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The Commonwealth of Massachusetts

15th ANNUAL REPORT

OF THE

METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

FOR THE

YEAR ENDING NOVEMBER 30, 1926

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE
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REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court Assembled:

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1926, its

FIRST ANNUAL REPORT

I. Organization and Administration

The act establishing the Commission was approved on May 28, 1926. As the act provides that the Commissioner of the Metropolitan District Commission shall be chairman of the Commission, Davis B. Keniston of Boston became chairman, and on July 28, Charles M. Davenport of Boston, and Joseph H. Soliday of Dedham, under appointment by the Governor, qualified as associate commissioners. The members of the Commission met for organization on July 30, 1926, and at once proceeded upon the execution of their duties. Charles M. Davenport was chosen secretary *pro tempore* and has since acted in that capacity.

II. Duties of the Commission

1. *Ware River Supply*

The legislature, by Chapter 375 of the Acts of 1926, directed that the Commission should divert into the Wachusett Reservoir the flood flows of the Ware River, in excess of a flow of 85 million gallons daily, at a point near the village of Coldbrook by constructing a tunnel so designed that it may later be extended to divert also the waters of the Swift River into the Wachusett Reservoir, in substantial accordance with the plans and recommendations of the Joint Board on Water Supply Needs and Resources of the Commonwealth as contained in House Document No. 1550 of the year 1922. The principal features of the work to be performed in the near future under this legislative requirement are:

(1) About seven and possibly eight shafts varying in depth from approximately 200 to 600 feet are to be sunk along the line of the proposed tunnel to Coldbrook for the purpose of facilitating the tunnel construction. The shaft at the point of diversion near Coldbrook will later be used for admitting the flood flows of the Ware River into the tunnel.

(2) A tunnel will be excavated in the sound bedrock from a suitable point in the gorge of the Quinapoxet River where it flows into the Wachusett Reservoir near Oakdale to a suitable point of diversion on the Ware River near Coldbrook. This tunnel will be about 12 feet 9 inches in diameter and about 13½ miles long.

(3) A diversion dam and suitable control works to maintain the specified limit of diversion will be constructed across the Ware River near Coldbrook at the head of the intake shaft to the tunnel.

2. *Swift River Reservoir*

The Commission is further required to submit to the General Court not later than the first Wednesday in January, 1927, a draft of such legislation as it may deem necessary or advisable for the development of an adequate future supply from the Swift River. The Commission is authorized to take by purchase or otherwise such lands, water rights, easements and other property in the watershed of the Swift River as it may deem necessary or desirable in preparation for the development of this river as a potential water supply for future use.

3. *South Sudbury Supply*

The Commission is also required to consider various matters connected with the use of the waters from the Sudbury and Cochituate watersheds and to report

thereon to the General Court its findings and recommendations not later than December 1, 1926.

III. Engineering Department

Frank E. Winsor, of Providence, Rhode Island, was appointed chief engineer by the Commission and his appointment was approved by the Governor and Council on September 2, 1926. Mr. Winsor was formerly employed by the Metropolitan Sewerage Commission, by the Metropolitan Water Board in the construction of the Wachusett dam and aqueduct works and later by the Charles River Basin Commission. From 1906 to 1915, he was employed by the Board of Water Supply of the City of New York as engineer in charge of the Kensico and Hill View reservoirs and a portion of the Catskill Aqueduct. Since 1915, he has been chief engineer for the Water Supply Board of the City of Providence, for the construction of its new water supply. Mr. Winsor was able to close his work at Providence and reported for duty October 1, 1926.

The appointment of the following employees was approved by the Governor and Council and they reported for duty as follows: Karl R. Kennison, designing engineer, on October 16; Harold W. Horne, assistant division engineer in charge of surveys for the Ware River tunnel, on October 27; Walton H. Sears, mechanical engineer, on November 29; N. LeRoy Hammond, assistant division engineer in charge of surveys in the Swift River valley, reported from time to time during the month of November, and will report permanently on December 1.

X. H. Goodnough, chief engineer of the State Department of Public Health, has been employed on a permanent basis as consulting engineer. J. Waldo Smith of New York City, formerly chief engineer for the Board of Water Supply of the city of New York, and Charles T. Main of Boston have been selected and employed from time to time as consulting engineers, and Charles P. Berkey of Columbia University as consulting geologist.

IV. Offices of the Commission

The Commission at first occupied space in the quarters of the Metropolitan District Commission at 1 Ashburton Place, Boston. On October 20, 1926, a lease was executed for rooms numbered 806 to 818 in the Five Cents Savings Bank building at 24 School Street, and on October 29, the offices of the Commission and of the chief engineer were established at this location. A field office for the Ware River division was temporarily established at the Wachusett Dam, Clinton, on November 1, and was moved to a permanent office in Holden on November 15. A field force began work in the Swift Reservoir division at Enfield on November 10, and an office was established at Enfield in what is known as the Felton Block on November 14.

V. Progress of the Work

The chief engineer, immediately upon reporting for duty October 1, started the organization of an engineering force. He has to date examined and carefully considered approximately 300 applications for employment. The engineering and office force on November 30 comprised a total of 48 employees divided as follows:

Headquarters Office	23
Ware River Division	12
Swift Reservoir Division	13

1. *Ware River Supply*

A field force started work October 27, on surveys to locate suitable shaft sites on the line of the proposed tunnel from the Wachusett Reservoir near Oakdale to the Ware River at Coldbrook. A contract has been let for borings to determine the location of proper ledge structure for the line of tunnel. It is expected if this work progresses satisfactorily that the actual work of shaft excavation will start in the spring.

2. *Swift River Reservoir*

Field work was begun November 10 on surveys of real estate offered for sale, and on the establishment of survey lines for the convenient location of all real estate in the Swift River valley. The Commission has proceeded as rapidly as possible in purchasing such rights and property as will later be required in the construction of works in the valley. All property offered for sale has been examined as rapidly as possible to determine if it is within the area to be required, and the valuations of such property as will be required has been estimated and negotiations undertaken with the owners. For these purposes local appraisers and agents have been employed. To date over seventy applications from owners offering to sell have been received. Options have been taken on two properties but no actual transfers have yet been made.

Borings, to supplement those obtained in 1920 and 1921 by the Joint Board on Water Supply Needs and Resources of the Commonwealth, have been started to determine the location and character of bedrock and overlying material at sites of the main dam and dike of the proposed reservoir, in order to further check these prior examinations for the purpose of presenting the legislation required, and to facilitate actual construction work later if authorized. It is expected at this date to prepare and file on January 5, 1927, the legislation required for the development of the Swift River supply.

A contract has been made for an aerial survey of the entire Swift River valley, and the survey has been completed for the east and middle branches of the river. The first fall of snow came before the west branch had been surveyed and prevented the completion of that part of the survey.

3. *South Sudbury Supply*

In the consideration of the various matters connected with the use of the waters from the Sudbury and Cochituate watersheds referred to the Commission for report, various surveys have been made and available data studied. On November 30, the Commission's report was ready for filing as required, together with a draft of legislation proposed to carry its recommendations into effect. (Printed as House Document 221 of 1927.)

VI. Financial Statement

The Commission presents the following abstract of its expenditures and disbursements from the time of its organization until and including November 30, 1926:

Expenditures to November 30, 1926

General Overhead

Unassigned supplies and equipment		$1,907.12	
Administration:			
Salaries of Commissioners	$3,612.86		
Salaries, Clerical, Commissioners' Office	480.00		
Miscellaneous Expense, Commissioners' Office	108.36		
Total Administration		4,201.22	
Engineering:			
Furniture and Equipment, Boston Office	$686.21		
Salaries of Engineering Staff, Boston Office	4,843.70		
Salaries, Clerical, Engineering Office	268.00		
General Consultant Expense	1,599.85		
Miscellaneous Expense, Boston Eng. Office	183.38		
Total Engineering		7,581.14	
Total General Overhead			$13,689.48

South Sudbury Supply

South Sudbury Engineering:			
Furniture and Equipment	$1,272.75		
Salaries	153.89		
Consultant Expense	1,290.62		
Miscellaneous Expense	16.24		
Automobile Maintenance	13.18		
Total South Sudbury Engineering		$2,746.68	
Total South Sudbury Supply			2,746.68

Ware River Supply—Including Wachusett-Coldbrook Tunnel

Ware Supply Engineering:			
Furniture and Equipment, Holden Office	$2,471.90		
Salaries, Holden Office	1,344.79		
Miscellaneous Expense, Holden Office	84.18		
Automobile Maintenance, Holden Office	26.36		
Total Ware Supply Engineering		$3,927.23	
Total Ware River Supply			$3,927.23

Swift River Reservoir

Swift Reservoir Engineering:			
Furniture and Equipment, Enfield Office	$2,068.35		
Salaries, Enfield Office	347.47		
Miscellaneous Expense, Enfield Office	37.06		
Automobile Maintenance, Enfield Office	13.18		
Total Swift Reservoir Engineering		$2,466.06	
Swift Reservoir Real Estate:			
Legal and Expert Expense	131.05		
Total Swift Reservoir Real Estate		131.05	
Total Swift River Reservoir			$2,597.11

Summary

General Overhead	$13,689.48	
South Sudbury Supply	2,746.68	
Ware River Supply, including Wachusett-Coldbrook Tunnel	3,927.23	
Swift River Reservoir	2,597.11	
Total to November 30, 1926		$22,960.50

VII. Recommendations and Reports

The excess of the present consumption of water by the Metropolitan Water District over the safe yield of its sources of supply of satisfactory quality is resulting in the gradual depletion of the Wachusett Reservoir at the rate of about 5½ billion gallons yearly. Even if the next few years should prove to be of more than average wetness, there will not be a sufficient quantity in storage to insure the present excellent quality of the supply. An additional supply should be obtained during the year 1927, or not later than during the year 1928, sooner than it can be obtained from the Ware River or by filtration of the South Sudbury source. The additional supply from the South Sudbury source in the manner recommended in the report now ready for filing should be authorized early in 1927 to allow the

completion of the work in time to obtain the benefit of the winter and spring flows of 1928.

The plan of developing the Swift River supply having been approved by Chapter 375 of the Acts of 1926, nothing is to be gained by delay, and actual development and construction work should be authorized and commenced.

The report of the chief engineer, explaining in detail the work of the engineering department, is herewith presented.

Respectfully submitted,

Davis B. Keniston
Charles M. Davenport
Joseph H. Soliday
Metropolitan District Water Supply Commission.

Boston, Mass., January 15, 1927.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission:

Gentlemen:

The following is a report of the operations of the engineering department from October 1, the date when I reported for duty as chief engineer, to November 30, which is the date of this report.

The total period covered by the report is only two months and a considerable part of this time has necessarily been spent in the organization of the engineering force required to make the necessary surveys, investigations and designs preparatory to the actual work of construction, and in locating and establishing the necessary offices and installing therein instruments, furniture and supplies. In order to comply with the provision of Chapter 375 of the Acts of 1926, requiring the filing on December 1 of a report with findings and recommendations together with proposed legislation for the development of the waters of the Sudbury and Cochituate watersheds to increase the Metropolitan District's available supply of water of satisfactory quality, immediate attention was given to this problem and a report was made to you on November 26, as hereinafter described, to be attached to your report of December 1. (House Document 221 of 1927.)

In addition to the work of organization and the preparation of the above report, a suitable general form of contract was prepared for the various items of work which will be undertaken, and to date three contracts have been entered into, all for preliminary investigations.

A more detailed report of these operations is contained in the following subdivision under the headings of the different departments of the work.

Headquarters Office

Through the courtesy of Chairman Keniston of the Metropolitan District Commission, temporary office room was obtained October 1 at 1 Ashburton Place, the headquarters of that Commission. This office was occupied until October 29, when the force was removed to the present quarters at 24 School Street.

Karl R. Kennison was appointed designing engineer and reported for duty October 16. Walton H. Sears was appointed mechanical engineer and reported for duty November 29. Harold W. Horne and N. LeRoy Hammond were appointed assistant division engineers in charge of the field work on the Ware and Swift supplies with offices at Holden and Enfield respectively, established as described in this report. The work of organizing the engineering force has progressed until the total on November 30 is as follows:

PERSONNEL OF ENGINEERING DEPARTMENT

Classification	*Appointed*	*Resigned*	*Total*	
HEADQUARTERS OFFICE:				
Chief Engineer	1		1	
Designing Engineer	1		1	
Mechanical Engineer	1		1	
Assistant Engineers	6		6	
Draftsmen, Rodmen	6		6	
Stenographers	6	2	4	
Bookkeeper, Clerks, Office Boy	4		4	
				23
HOLDEN OFFICE:				
Assistant Division Engineer	1		1	
Assistant Engineers	3		3	
Inspectors, Rodmen	7		7	
Axemen	1		1	
				12
ENFIELD OFFICE:				
Assistant Division Engineer	1		1	
Assistant Engineers	2		2	
Instrumentmen, Rodmen	10		10	
				13
				48

The force at the Headquarters Office includes those engaged in surveys for the South Sudbury supply which to date is operating from the Boston office.

X. H. Goodnough, chief engineer of the Department of Public Health, J. Waldo Smith, formerly chief engineer of the New York Board of Water Supply, and Charles T. Main of Boston have been consulted from time to time, and Charles P. Berkey, geologist of Columbia University, has advised as to the location of the Ware River tunnel.

South Sudbury Supply

The recommendations of the Metropolitan District Commission relative to making available by filtration or chlorination, or both, the waters of the Sudbury and Cochituate watersheds, as referred to in the report of the Metropolitan Water Supply Investigation Commission in House Document No. 900 of 1926, have been carefully considered and further studies have been made to determine the best plan of such development. The outstanding fact is that the present critical period of reduced storage in Wachusett Reservoir requires prompt action to reinforce at the earliest possible date the existing sources of supply of good quality and that a comprehensive plan of developing the yield of the entire South Sudbury area by filtration will involve delays nearly as great as those involved in the development of the Ware River supply at Coldbrook. The construction of the tunnel to the Ware River already authorized by Chapter 375 of the Acts of 1926 may possibly be sufficiently advanced to store the Ware River spring floods in the Wachusett Reservoir in 1931, but probably a year later or in 1932. If the filtration of the Southern Sudbury sources were undertaken, this additional supply could not be made available before 1930.

In view of the existing emergency, a plan has been developed for diverting into the main Sudbury Reservoir, and thus adding to the present supply, the waters from certain selected areas at the headwaters of the South Sudbury watershed which will not require filtration and which can be made to add 15 million gallons daily to the existing supply. This increase, together with other amounts available in an emergency from Lake Cochituate, will safely yield an additional 23 million gallons daily throughout a critically dry period; and this plan as recommended makes it possible to further increase this yield in an emergency by the addition of such flood flows as may upon careful analysis prove to be suitable by direct

pumping from the Sudbury River in addition to the diversions from the headwaters above referred to.

My report to you of November 26 (published in House Document 221 of 1927) describes in detail this proposal to use the South Sudbury and Cochituate sources of water supply for the Metropolitan District, and covers the sanitary requirements of the Sudbury River below Dam No. 1, the requirements of the town of Framingham for a water supply from the district sources, and the matter of sewerage in the town of Ashland.

In spite of any steps that can be taken to meet the existing emergency, the amount of storage in the Wachusett Reservoir will probably remain for the next three or four years at a level so low as to make it questionable whether satisfactory purification can continue to be obtained without chlorination of the entire supply. Furthermore, it may be necessary to chlorinate the diversions herein proposed from these headwaters reservoirs in the Southern Sudbury area, and it will doubtless be necessary to chlorinate the water from Lake Cochituate.

Apparatus for chlorinating the entire supply as it leaves Chestnut Hill Reservoir and for chlorinating the waters of the Weston Aqueduct at or near its terminus should be installed at once for use if and when needed.

The surveys required in the preparation of this report were conducted from the headquarters office. Negotiations have been undertaken looking to the establishment of an office in Framingham to continue the surveys necessary to perfect the proposed plan of diversion and to secure additional data required for early preparation of contracts in the event that this proposed legislation is passed. Some of the equipment necessary for this office has been purchased.

Weston & Sampson, consulting engineers of Boston, have made periodical analyses of the waters of the Sudbury River during the last five months and reported their findings from time to time.

Ware River Supply

Mr. Horne, assistant division engineer, reported for duty October 27. He and his force occupied temporary quarters, provided by the Metropolitan District Commission at the Wachusett Dam at Clinton, on November 1. On November 15, the force removed to the present field office conveniently located in Holden Center.

Surveys have been started to locate suitable shaft sites on the line of the proposed tunnel from the Wachusett Reservoir near Oakdale to the Ware River at Coldbrook.

Contract No. 1 for borings to determine the surface of sound ledge along the line of the tunnel was prepared and advertised October 26. Five bids were received and opened on November 5. The two lowest were as follows:

	Pennsylvania Drilling Co., Pittsburgh, Pa.	Sprague & Henwood, Inc., Scranton, Pa.
Item 1—	*Unit Price*	*Unit Price*
300 Linear ft.		
Wash Borings	$2.50	$4.35
Item 2—		
1200 Linear ft.		
Core Borings to the surface of sound bedrock	3.50	4.35
Item 3—		
700 Linear ft.		
Core Borings in sound bedrock . .	4.50	4.35
Item 4—		
200 Linear ft.		
Casing ordered left in place . . .	.80	.80
Total	$8,260.00	$9,730.00

This Contract, No. 1, was awarded to the low bidder, the Pennsylvania Drilling Company of Pittsburgh, Pennsylvania, and was executed under date of November 15, 1926. The work completed to November 30 under this contract was:

Item 2—643.4 feet core borings to sound bed rock.
Item 3—145.4 feet core borings in sound bed rock.

Swift River Reservoir

Mr. Hammond, assistant division engineer, has reported for duty from time to time during the month of November pending such time as his services may be continuously available.

The field work was begun November 10, and a field office was established in Enfield November 14 in the Felton Block, conveniently located near the town center.

The work of the field office has consisted principally of surveys of real estate offered for sale to the commission and in the establishment of survey lines and stations for the convenient location of all such property in the Swift River valley. To date, seventy-three requests have been received from the owners of real estate located in and near the Swift River valley for an appraisal by the commission of the value of their holdings. All such property that is located within the limits of the proposed reservoir or sufficiently near its margins to make it desirable for the commission to purchase it is promptly referred to appraisers for a report as to its value. Several of these reports have been made and are under advisement by the commission, but no actual purchases of real estate were made prior to November 30.

Borings, to supplement those obtained in 1920 and 1921 by the Joint Board on Water Supply Needs and Resources of the Commonwealth, were begun to determine the location and character of bedrock and overlying material at sites of the main dam and dike of the proposed reservoir under Contract No. 2, entered into with Sprague & Henwood, Inc., Scranton, Pennsylvania, on November 12. This Contract calls for Items 1, 2 and 3, wash borings, core borings to the surface of sound bedrock and core borings in sound bedrock, respectively, a total of 2200 linear feet, all at $4.35 per linear foot; and for casings ordered left in place, $0.80 per linear foot. The total amount of the contract is estimated at $9,730. No holes were completed under this contract prior to November 30.

Contract No. 3 was entered into with the Fairchild Aerial Surveys, Inc., New York City, on November 22, for furnishing photographs obtained from aerial surveys of the entire Swift River valley. This Contract calls for photographing the entire area of the west, middle and east branches of the Swift River extending from a point below the proposed dam and dike sites on the south to the Millers River on the north, and including the entire area about Pottapaug Pond on the east; and for delivering one complete set of contract prints at a scale of approximately 1 inch equals 1200 feet. The Contract also provides for the furnishing, if required, of additional contact prints and of enlargements to a scale of 1 inch equals 400 feet. The total amount of the contract is estimated at $6,955. The contractor proceeded at once to photograph as much of the area as possible before weather conditions should interrupt. The last flight on the last day suitable for aerial photography before the first fall of snow was made November 28. The entire middle and east branches of the river have been covered to date leaving the west branch not yet photographed.

Summary of Contracts

No.	Contractor	Work Involved	Division	Estimated amount of Contract
1	Pennsylvania Drilling Co.	Borings	Ware River Supply	$8,260
2	Sprague & Henwood, Inc.	Borings	Swift River Supply	9,730
3	Fairchild Aerial Surveys, Inc.	Aerial Surveys	Swift River Supply	6,955

Respectfully submitetd,

24 School Street, Boston, Mass.
December 1, 1926

Frank E. Winsor,
Chief Engineer.

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court Assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1927, its

SECOND ANNUAL REPORT

I. Organization and Administration

There has been no change in the personnel of the Commission during the year. Davis B. Keniston has continued as Chairman, and Charles M. Davenport and Joseph H. Soliday as associate commissioners. Charles M. Davenport continued to act as secretary until March, 1927, when R. Nelson Molt became secretary.

The clerical force of the Commission's office at Boston has been organized during the year and on November 30, 1927, consisted, in addition to the secretary, of one senior clerk, one bookkeeper, one clerk and one stenographer. Two title examiners have been employed in the field. A real estate purchasing agent and conveyancers have been employed from time to time as required.

The engineering and clerical force of the engineering department has been built up from 48 employees on November 30, 1926, to a total of 133 employees on November 30, 1927. The maximum force during the year was 138 during the week ending August 13, 1927, and the average force was 100.

II. Engineering Department

Frank E. Winsor has continued as chief engineer. Karl R. Kennison has continued as designing engineer and Walton H. Sears as mechanical engineer.

Three division engineers are in charge of field divisions as follows: Harold W. Horne, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; and N. LeRoy Hammond, Swift River Reservoir Division. Harold W. Horne continued as assistant division engineer from last year and N. LeRoy Hammond reported permanently for duty as assistant division engineer on December 1, 1926. They were promoted to division engineers on June 1, 1927. Richard R. Bradbury reported for duty as division engineer on August 1, 1927.

X. H. Goodnough, Chief Engineer of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, have continued as consulting engineers. Charles T. Main of Boston has been employed from time to time as consulting engineer on mill and water power damages, and Professor Charles P. Berkey of Columbia University as consulting geologist.

III. Offices

Since the beginning of the year the offices of the Commission and of the Chief Engineer have been in the Five Cents Savings Bank Building at 24 School Street, Boston.

Four field offices have been maintained for the whole or parts of the year. That of the Wachusett-Coldbrook Tunnel Division was continued at Holden Center and that of the Swift River Reservoir Division was continued at Enfield. Headquarters for the Coldbrook-Swift Tunnel Division were established at Hardwick on September 15, 1927, and for the Southern Sudbury Emergency Supply at Framingham on December 20, 1926.

IV. Real Estate

During the year 667 requests have been received from the owners of real estate, located in and near the Swift River Valley, for appraisal by the Commission of the value of their holdings, making a total of 740 such requests to date.

The total included in these parcels of land whose owners have thus indicated their willingness to sell is approximately 32,200 acres, all but about 2,500 acres

of which may be required to be purchased. Property offered for sale that is located within the limits of the proposed reservoir or sufficiently near its margin to make it desirable for protection has generally been referred to the appraisers of the Commission for a report as to its value. To date nearly 11,000 acres have been purchased and about 4,700 more are under option. Tables showing the distribution of this acreage among the various towns in the Swift Valley and showing the progress of real estate acquisitions throughout the year are appended hereto.

A width of at least 50 feet was taken for the Wachusett-Coldbrook Tunnel, 25 feet each side of the center line. In general the land required for the tunnel was taken in fee. On parts of the tunnel line between shafts an easement for the tunnel construction, operation and maintenance was taken and, in the same location where practicable, an easement for the construction, operation and maintenance of an electric transmission line was also taken. In some places, however, easements were taken for the transmission line and for access to the shafts other than along the center line of the tunnel. The land required for camp sites and spoil banks at the various shafts was taken in fee.

The pipe lines for the Southern Sudbury Emergency Supply required in general the taking of an easement across private property of varying widths. The land required for the pumping station on the pipe line from Hopkinton Reservoir to Sudbury Reservoir and for outlet works at the end of this line was taken in fee. Also the land required for the Whitehall open channel, small diversion dam and reservoir in the town of Hopkinton was taken in fee.

The line from Hopkinton Reservoir to Sudbury Reservoir was laid a distance of approximately 3,200 feet in the public highways where no taking of private land but only an easement in the highway was required. Similarly the Ashland pipe line followed the public highways for a distance of approximately 4,150 feet.

V. Danger of Water Shortage

The shortage in the water supply for the Metropolitan District was so imminent and apparent to the Legislature in 1926 when the Ware River legislation, Chapter 375, Acts of 1926, was enacted, that in the act the Commission to be appointed was expressly directed to proceed forthwith with the work contemplated in that enactment. By the winter of 1927, the danger of a water shortage, with the Wachusett Reservoir, the main source of supply, half empty, was more apparent than in the previous year. The Legislature of 1927 therefore enacted Chapter 111, Acts of 1927, for an emergency supply from the head waters of the Sudbury River in the Southern Sudbury region for immediately augmenting existing supplies. In this legislation, it was also provided that the work should proceed forthwith. In 1927 the Legislature further enacted the definitive legislation for the Swift River development, Chapter 321, Acts of 1927, and again expressly directed the Commission to proceed forthwith with the work. Every effort has been made by the Commission to carry out these emergency injunctions of the Legislature.

The Southern Sudbury emergency water supply provided for in Chapter 111, Acts of 1927, was made available, in part, for use about six months from the passage of the legislation and the progress to date insures its being wholly available by the end of the calendar year. All possible speed has been exercised by the Commission to make the flood waters from the Ware River supply provided for in Chapter 375, Acts of 1926, available not later than the winter and spring of 1931, the shortest time structurally feasible. Unusual rainfalls in the late fall have temporarily relieved the current shortage impending for 1928, but have not altered the general situation requiring that the additional supply be made available at the earliest possible date, and not later than the spring of 1931.

VI. Progress of the Work

Studies have been made to determine the probable effect of the proposed takings by the Metropolitan District upon the flow of the Connecticut River. The matter is more fully discussed in the report of the Chief Engineer appended hereto.

Early in the year 1927 the Commission, through its Chief Engineer, presented data and contemplated plans for the Ware River and Swift River projects to the District Engineer of the Corps of Engineers, United States Army. Applications have been made and are now pending before the War Department for formal

permits for the diversion from the Ware River, as authorized under Chapter 375 of the Acts of 1926, and for the diversion from the Swift River, as authorized by Chapter 321, Acts of 1927.

Ware River Supply

Surveys were continued to locate suitable shaft sites on the line of the Wachusett-Coldbrook Tunnel, and Contract 1, for borings along the line of the tunnel, was continued to determine the location of proper ledge rock structure for the tunnel and shafts.

On April 27, 1927, Contract 10 was made with the New England Power Co. for constructing, maintaining and operating a 22,000 volt transmission line connecting all shafts of the Wachusett-Coldbrook Tunnel. The purpose of this transmission line is to furnish power for the construction of the shafts and tunnel. Its construction was completed June 20, and it is to be maintained and operated during the period of construction of the tunnel or any extension of it.

Six construction shafts have been sunk along the line of the Wachusett-Coldbrook Tunnel. Contract 4, for sinking Shaft 5, and Contract 8, for sinking Shafts 6 and 7 in the Town of Rutland, were awarded to James J. Coughlan & Sons, Inc., Boston, Mass., on March 28, 1927, and May 24, 1927, respectively. Contract 12, for sinking Shafts 2, 3 and 4 in the Towns of Holden and Rutland, was awarded to the Dravo Contracting Co., Pittsburgh, Pa., on May 24, 1927. The lining has been completed in all shafts under construction, 2 to 7, inclusive, and excavation is being made in the tunnel at the shaft bottoms. At Shaft 2 tunnel excavation, beyond the limits set by the original contract, has been continued by the contractor at a modified price.

Bids for the construction of the Wachusett-Coldbrook Tunnel, including Shafts 1 and 8, the outlet and intake respectively, were opened November 18, 1927, but the contract has not yet been awarded.

Swift River Supply

As required under the provisions of Chapter 375, Acts of 1926, this Commission submitted to the General Court on the first Wednesday in January, 1927, a draft of legislation for the development of an adequate future water supply from the Swift River. The Swift River legislation, Chapter 321, approved April 26, 1927, provides for the immediate extension of the Wachusett-Coldbrook Tunnel to the Swift River, the construction of a storage reservoir in the Swift Valley and the diversion of the total flow in excess of 20 million gallons daily guaranteed at Bondsville about five miles downstream from the main dam. Chapter 321 authorizes an expenditure of $50,000,000 in addition to $15,000,000, authorized by Chapter 375, Acts of 1926, and in addition to $900,000 authorized by Chapter 111, Acts of 1927.

Surveys of real estate have been continued during the year. Topographic surveys have been made of the dam and dike sites and portions of the reservoir area, and studies made for highway relocations.

Contract 2, for borings at the dam and dike sites, was continued to determine the location and character of bed rock and overlying material.

Aerial surveys have been made by the Fairchild Aerial Surveys, Inc., of the entire Swift River Valley, Contract 3, and along the Chicopee and Ware Rivers, Contract 9.

A census has been made of burials in all cemeteries which may be affected by the reservoir. The work of copying inscriptions and locating each headstone or monument has been partially completed.

Southern Sudbury Emergency Supply

The report of the Commission recommending that an additional emergency supply be made available from the Southern Sudbury sources, published as House Bill 221 of 1927, was filed December 1, 1926. The legislation as approved on March 15, 1927, in Chapter 111, provided for the diversion, if required for emergency use, of the inferior waters of Whitehall and Hopkinton Reservoirs, and of the Sudbury River at Cordaville into the main Sudbury Reservoir, and of Ashland Reservoir into the Sudbury Aqueduct, authorizing therefor an expenditure of $900,000.

On September 2, 1927, a taking was made of all the waters of Indian Brook at a point at or immediately below the dam of the Hopkinton Reservoir of the metropolitan water district, in the Town of Ashland, for diversion into the Sudbury Reservoir or Sudbury Aqueduct of the district, or both.

Seven contracts for this work were awarded during the year. These included four contracts for pipe lines totalling approximately 37,000 feet in length; one contract for a small pumping station; one contract for an open channel approximately 5,000 feet in length; and one contract for the furnishing of electric power for operation of the pumping station.

Provision has been made for chlorinating the entire supply and for the construction, if later deemed desirable, of a decolorizing plant at the outlet of the Hopkinton line into the Sudbury Reservoir.

At the request of the selectmen of the Town of Southborough and at their expense three fire hydrants were installed on the pipe line from Hopkinton Reservoir to Sudbury Reservoir in the vicinity of the Village of Cordaville. These hydrants will be available for connection to pumping engines at such time as the pipe line is in use, but no obligation has been assumed to keep water in this line.

Actual diversion from the Hopkinton Reservoir into the Sudbury Reservoir was begun on November 15 at the rate of 5 million gallons per day and was continued at this rate throughout the month.

VII. Financial Statement

The Commission presents the following abstract of its expenditures and disbursements from July 28, 1926, to and including November 30, 1927:

General Overhead

	Year Ending Nov. 30, 1927	Total to Nov. 30, 1927
Administration:		
Salaries, Commissioners	$10,499.94	$14,112.80
Salaries, Clerical, Commissioners' Office	7,039.03	7,519.03
Furniture and Equipment, Commissioners' Office	2,237.15	2,237.15
General Legal Expense, Commissioners' Office	414.48	414.48
Automobile Maintenance, Commissioners' Office	249.77	249.77
Miscellaneous Expense, Commissioners' Office	4,023.22	4,131.58
Total Administration	$24,463.59	$28,664.81
Engineering, Headquarters Office:		
Salaries, Engineering	$62,961.11	$67,804.81
Salaries, Clerical	8,329.90	8,597.90
General Consultant Expense	7,480.59	9,080.44
Furniture and Equipment	7,565.08	8,408.09
Rent and Upkeep	11,840.15	11,840.15
Automobile Maintenance	247.77	257.30
Miscellaneous Expense	4,726.40	5,010.21
Total Engineering, Headquarters Office	$103,151.00	$110,998.90
Unassigned:		
Unassigned Supplies and Equipment	—$39.00	$1,573.98
Total Unassigned	—$39.00	$1,573.98
Total General Overhead	$127,575.59	$141,237.69

Distribution of General Overhead

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
Administration:		
Wachusett-Coldbrook Tunnel Division	$9,799.39	$10,975.73
Coldbrook-Swift Tunnel Division	1,349.37	1,349.37
Swift River Reservoir Division	7,378.94	9,017.42
Southern Sudbury Emergency Supply	5,935.89	7,322.29
Total Administration	$24,463.59	$28,664.81
Engineering, Headquarters Office:		
Wachusett-Coldbrook Tunnel Division	$41,039.57	$43,380.30
Coldbrook-Swift Tunnel Division	4,643.29	4,643.29
Swift River Reservoir Division	31,705.73	34,817.99
Southern Sudbury Emergency Supply	25,762.41	28,157.32
Total Engineering, Headquarters Office	$103,151.00	$110,998.90

Wachusett-Coldbrook Tunnel Division

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
General Overhead:		
Administration	$9,799.39	$10,975.73
Engineering	41,039.57	43,380.30
Total General Overhead	$50,838.96	$54,356.03
Engineering:		
Salaries, Engineering and Clerical	$45,728.15	$47,072.94
Furniture and Equipment	7,212.74	9,684.64
Automobile Maintenance	2,228.12	2,254.48
Miscellaneous Expense	18,964.28	19,056.66
Consulting Expense	545.65	545.65
Rent and Upkeep	1,934.56	1,934.56
Total Engineering	$76,613.50	$80,548.93
Real Estate:		
Legal and Expert Expense	$2,044.05	$2,044.05
Miscellaneous Expense	225.00	225.00
Purchases and Settlements	16,560.00	16,560.00
Taxes	104.34	104.34
Total Real Estate	$18,933.39	$18,933.39
Ware Watershed Protection:		
Legal and Expert Expense	$448.33	$448.33
Consultant Expense	566.40	566.40
Labor	470.00	470.00
Miscellaneous Expense	22.21	22.21
Purchases and Settlements	223,283.18	223,283.18
Taxes	4,960.92	4,960.92
Total Ware Watershed Protection	$229,751.04	$229,751.04
Ware Supply Damages:		
Consultant Expense	$591.70	$591.70
Total Ware Supply Damages	$591.70	$591.70
Ware Diversion Damages:		
Consultant Expense	$452.39	$452.39
Miscellaneous Expense	1,265.00	1,265.00
Total Ware Diversion Damages	$1,717.39	$1,717.39
Contracts:		
Contract No. 4 — Sinking Shaft 5	$92,423.16	$92,423.16
Contract No. 8 — Sinking Shafts 6 and 7	121,166.73	121,166.73
Contract No. 10 — Constructing Transmission Line	88,606.59	88,606.59
Contract No. 12 — Sinking Shafts 2, 3 and 4	181,163.16	181,163.16
Total Contracts	$483,359.64	$483,359.64
Permanent Construction except Contracts:		
Miscellaneous Expense	$441.44	$441.44
Total	$441.44	$441.44
Total Wachusett-Coldbrook Tunnel Division	$862,247.06	$869,699.56

Coldbrook-Swift Tunnel Division

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
General Overhead:		
Administration	$1,349.37	$1,349.37
Engineering	4,643.29	4,643.29
Total General Overhead	$5,992.66	$5,992.66
Engineering:		
Salaries, Engineering and Clerical	$7,661.50	$7,661.50
Furniture and Equipment	3,796.37	3,796.37
Automobile Maintenance	611.15	611.15
Miscellaneous Expense	8,731.08	8,731.08
Rent and Upkeep	89.40	89.40
Total Engineering	$20,889.50	$20,889.50
Real Estate:		
Legal and Expert Expense	$192.84	$192.84
Miscellaneous Expense	7.50	7.50
Total Real Estate	$200.34	$200.34

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
PERMANENT CONSTRUCTION EXCEPT CONTRACTS:		
Miscellaneous Expense	$91.87	$91.87
Total	$91.87	$91.87
Total Coldbrook-Swift Tunnel Division	$27,174.37	$27,174.37

SWIFT RIVER RESERVOIR DIVISION

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
GENERAL OVERHEAD:		
Administration	$7,378.94	$9,017.42
Engineering	31,705.73	34,817.99
Total General Overhead	$39,084.67	$43,835.41
ENGINEERING:		
Salaries, Engineering and Clerical	$53,662.58	$54,010.05
Furniture and Equipment	6,015.33	8,083.68
Automobile Maintenance	1,991.96	2,005.14
Miscellaneous Expense	38,882.86	38,925.14
Rent and Upkeep	230.64	230.64
Total Engineering	$100,783.37	$103,254.65
REAL ESTATE:		
Legal and Expert Expense	$27,867.25	$27,998.30
Miscellaneous	541.15	541.15
Purchases and Settlements	960,802.08	960,802.08
Taxes	4,367.31	4,367.31
Total Real Estate	$993,577.79	$993,708.84
SWIFT RESERVOIR DAMAGES:		
Consultant Expense	$921.47	$921.47
Total Swift Reservoir Damages	$921.47	$921.47
SWIFT DIVERSION DAMAGES:		
Consultant Expense	$1,360.54	$1,360.54
Miscellaneous Expense	1,369.21	1,369.21
Total Swift Diversion Damages	$2,729.75	$2,729.75
PERMANENT CONSTRUCTION EXCEPT CONTRACTS:		
Miscellaneous Expense	$214.78	$214.78
Total	$214.78	$214.78
Total Swift River Reservoir Division	$1,137,311.83	$1,144,664.90

SOUTHERN SUDBURY EMERGENCY SUPPLY

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
GENERAL OVERHEAD:		
Administration	$5,935.89	$7,322.29
Engineering	25,762.41	28,157.32
Total General Overhead	$31,698.30	$35,479.61
ENGINEERING:		
Salaries	$26,179.25	$26,333.14
Furniture and Equipment	3,667.86	4,940.61
Automobile Maintenance	965.03	978.21
Miscellaneous Expense	1,832.84	1,863.04
Consultant Expense	2,525.63	3,816.25
Labor	173.00	173.00
Rent and Upkeep	425.18	425.18
Total Engineering	$35,768.79	$38,529.43
REAL ESTATE:		
Legal and Expert Expense	$1,176.60	$1,176.60
Consultant Expense	30.00	30.00
Purchases and Settlements	7,038.22	7,038.22
Total Real Estate	$8,244.82	$8,244.82
SOUTHERN SUDBURY DIVERSION DAMAGES:		
Consultant Expense	$869.50	$869.50
Settlements	24,000.00	24,000.00
Total Southern Sudbury Diversion Damages	$24,869.50	$24,869.50

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
CONTRACTS:		
Contract No. 5 — Cordaville Pipe Line	$74,181.73	$74,181.73
Contract No. 6 — Cordaville Pumping Station	13,985.23	13,985.23
Contract No. 7 — Hopkinton Pipe Line	112,836.10	112,836.10
Contract No. 11 — Ashland Pipe Line	110,042.86	110,042.86
Contract No. 13 — Whitehall Pipe Line	43,130.46	43,130.46
Contract No. 16 — Whitehall Open Channel	6,239.07	6,239.07
Total Contracts	$360,415.45	$360,415.45
PERMANENT CONSTRUCTION EXCEPT CONTRACTS:		
Miscellaneous Expense	$8,517.16	$8,517.16
Total	$8,517.16	$8,517.16
Total Southern Sudbury Emergency Supply	$469,514.02	$476,055.97

SUMMARY

	Year ending Nov. 30, 1927	Total to Nov. 30, 1927
Wachusett-Coldbrook Tunnel Division	$862,247.06	$869,699.56
Coldbrook-Swift Tunnel Division	27,174.37	27,174.37
Swift River Reservoir Division	1,137,311.83	1,144,664.90
Southern Sudbury Emergency Supply	469,514.02	476,055.97
Unassigned	—39.00	1,573.98
Grand Total	$2,496,208.28	$2,519,168.78

VIII. OTHER REPORTS

The report of the Chief Engineer explaining in detail the work of the engineering department is herewith presented. It includes a summary of information of geologic interest, in accordance with the requirements of Section 2 of Chapter 321, Acts of 1927.

Respectfully submitted,

DAVIS B. KENISTON,
CHARLES M. DAVENPORT,
JOSEPH H. SOLIDAY,
Metropolitan District Water Supply Commission.

24 SCHOOL STREET, BOSTON, MASSACHUSETTS.
January 14, 1928.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1927.

ORGANIZATION

The engineering organization has increased in numbers as the work of the department has expanded and construction begun.

Karl R. Kennison, Designing Engineer, has in charge all studies in connection with the general plan of the work and the design of structures, the preparation of contracts, specifications, contract and working drawings. He takes care, generally, of the executive work of the department.

Walton H. Sears, Mechanical Engineer, has in charge the collection of data for use in the settlement of mill and water power damages. He assists in the design of work of a mechanical nature and in the preparation of contracts and specifications.

Three Division Engineers are in charge of field divisions as follows: Harold W. Horne, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Swift River Reservoir Division.

Walter Knowles, Assistant Engineer, has in charge the field work for the Southern Sudbury Emergency Supply.

X. H. Goodnough, Chief Engineer of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, have continued as Consulting Engineers. Charles T. Main, consulting engineer of Boston, has reported on mill and water power damages. Professor

Charles P. Berkey, geologist of Columbia University, has advised as to sub-surface investigations, particularly in regard to the location of the tunnel from the Wachusett Reservoir to the future Swift River Reservoir, and in regard to dam and dike foundations.

The number of employees under the direction of the Chief Engineer at the end of the year and of the preceding year was as follows:

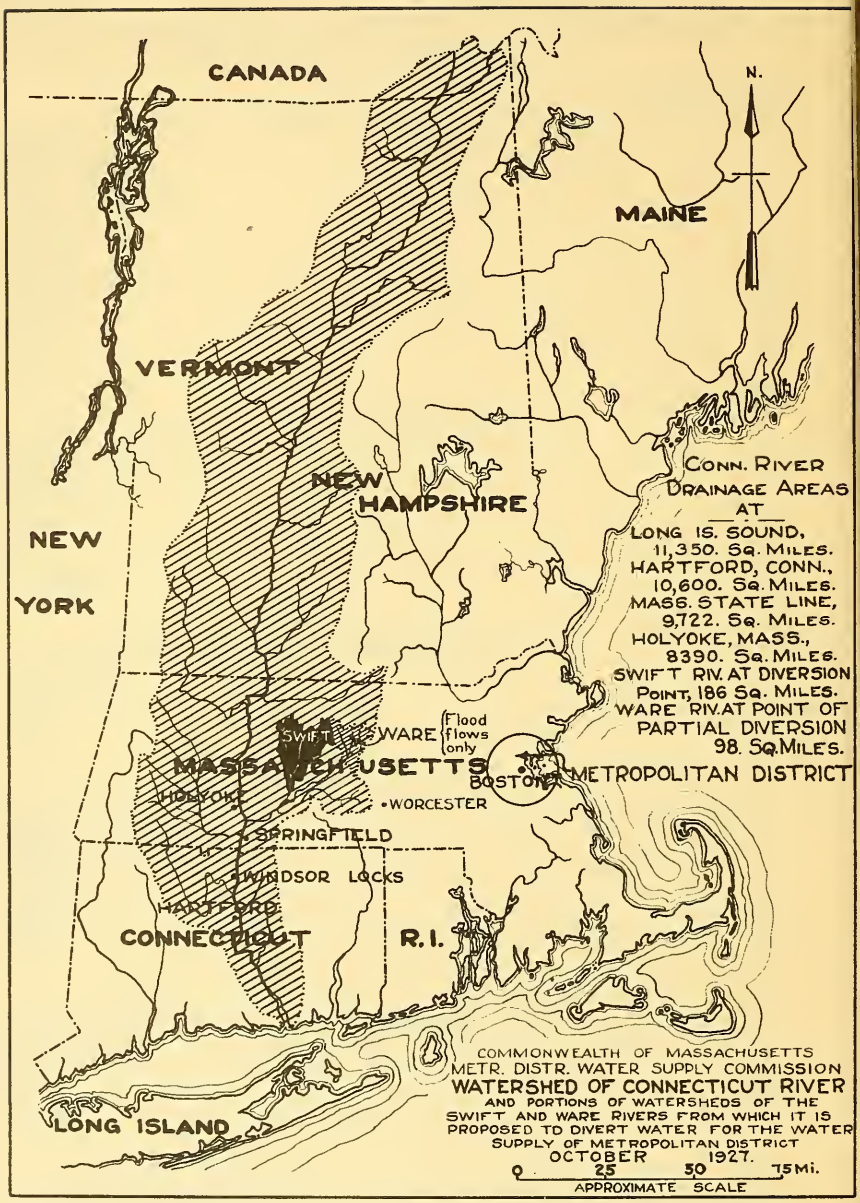
PERSONNEL OF ENGINEERING DEPARTMENT

Classification	Nov. 30, 1926	Nov. 30, 1927
HEADQUARTERS OFFICE, CHIEF ENGINEER AND DESIGNING DIVISION:		
Chief Engineer	1	1
Designing Engineer	1	1
Mechanical Engineer	1	1
Assistant Engineers	6	9
Draftsmen	2	6
Instrumentman	–	1
Rodmen	4	2
Senior Stenographer	–	1
Stenographers	4	3
Bookkeeper	1	–
Clerks	2	2
File Clerk	–	1
Office Boy	1	1
	23	29
HOLDEN OFFICE, WACHUSETT-COLDBROOK TUNNEL DIVISION:		
Division Engineer	–	1
Assistant Division Engineer	1	–
Assistant Engineers	3	5
Draftsmen	–	2
Instrumentmen	–	4
Rodmen	6	10
Axemen	1	3
Inspectors	1	7
Stenographer	–	1
	12	33
HARDWICK OFFICE, COLDBROOK-SWIFT TUNNEL DIVISION:		
Division Engineer	–	1
Assistant Engineers	–	2
Instrumentmen	–	3
Rodmen	–	8
Axemen	–	2
	–	16
ENFIELD OFFICE, SWIFT RIVER RESERVOIR DIVISION:		
Division Engineer	–	1
Assistant Division Engineer	1	–
Assistant Engineers	2	7
Draftsman	–	1
Instrumentmen	1	5
Rodmen	9	16
Axemen	–	6
Inspector	–	1
Clerk	–	1
	13	38
FRAMINGHAM OFFICE, SOUTHERN SUDBURY EMERGENCY SUPPLY:		
Assistant Engineers	–	4
Instrumentmen	–	3
Rodmen	–	4
Axemen	–	2
Inspectors	–	4
	–	17
Total Engineering Force	48	133

The maximum force during the year was 138, during the week ending August 13, 1927. The minimum force was 50, during the week ending December 4, 1926. The average force for the year was 100.

OFFICES

The office of the Chief Engineer and Designing Division was continued in the Five Cents Savings Bank Building at 24 School Street, Boston. The field office


CANADA
N.
MAINE
VERMONT
NEW HAMPSHIRE
NEW YORK
CONN. RIVER DRAINAGE AREAS AT
LONG IS. SOUND, 11,350. SQ. MILES.
HARTFORD, CONN., 10,600. SQ. MILES.
MASS. STATE LINE, 9,722. SQ. MILES.
HOLYOKE, MASS., 8390. SQ. MILES.
SWIFT RIV. AT DIVERSION POINT, 186 SQ. MILES.
WARE RIV. AT POINT OF PARTIAL DIVERSION 98. SQ. MILES.
SWIFT
WARE
Flood flows only
MASSACHUSETTS
BOSTON
METROPOLITAN DISTRICT
HOLYOKE
WORCESTER
SPRINGFIELD
WINDSOR LOCKS
HARTFORD
CONNECTICUT
R.I.
LONG ISLAND
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
WATERSHED OF CONNECTICUT RIVER
AND PORTIONS OF WATERSHEDS OF THE SWIFT AND WARE RIVERS FROM WHICH IT IS PROPOSED TO DIVERT WATER FOR THE WATER SUPPLY OF METROPOLITAN DISTRICT
OCTOBER 1927.
0 25 50 75 Mi.
APPROXIMATE SCALE

of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. On September 15, 1927, the field office of the Coldbrook-Swift Tunnel Division was established in the brick school building on the Common at Hardwick. The field office of the Swift River Reservoir Division was continued in the Felton Block at Enfield. The field office for the Southern Sudbury Emergency Supply was established on December 20, 1926, at 5 Hollis Street, Framingham.

Headquarters Office

Summary of the Year's Work

Legislation for Swift River Development. — In accordance with Chapter 375, Acts of 1926, a draft of legislation for the development of an adequate future water supply from the Swift River was required to be submitted by the Commission to the General Court on or before the first Wednesday in January, 1927.

Many engineering studies were made in connection with the preparation of this draft and its subsequent modification by legislative committees. On January 26, 1927, the various mill owners along the Chicopee and Swift Rivers, affected by the proposed diversion of the waters of the Swift River, were invited by the Chief Engineer to a conference for the purpose of expressing their views in the matter. Correspondence supplemented by various conferences was carried on with the District Engineer of the War Department prior to the passage of the Swift River legislation.

Effect of Ware and Swift River Diversions on Connecticut River Flows. — Studies have been made to determine the effect of the authorized diversions for the Metropolitan District of waters from the Swift and Ware Rivers upon the flow of the Connecticut River. The drainage areas of the Connecticut River at various points and of the Ware and Swift Rivers have been determined as follows:

Connecticut River Drainage Areas

	Square Miles
Connecticut River at Long Island Sound (entire area)	11,350
Connecticut River at Hartford, Conn.	10,600
Connecticut River at Windsor Locks, Conn.	9,760
Connecticut River at Massachusetts State Line	9,722
Connecticut River at Holyoke, Mass.	8,390
Ware River at Coldbrook (flood waters only taken and dry weather flow of Connecticut River not affected)	98
Swift River, including a small area at the head of Beaver Brook which now flows into the Ware River	186

These areas are also shown on the accompanying plan.

From the 186 square miles of the Swift River drainage area, enough water will, in accordance with the requirements of Chapter 321, Acts of 1927, be released at all times to insure a flow of 20 million gallons per day at Bondsville on the Swift River, about five miles below the proposed dam. The portion of the Swift River drainage area authorized to be diverted forms 1.64 per cent of the total drainage area of the Connecticut River, and 1.75 per cent of the drainage area at Hartford, but due to the above mentioned guaranteed flow of 20 million gallons daily, there will be no diminution of the natural flow at times of extreme drought, and the amount of water to be diverted in times of ordinary low flow during the driest months in the average year would be the equivalent of the total diversion of water from an area less than one per cent of the total drainage area of the Connecticut River.

Real Estate. — Reports with recommendations have been made to the Commission as to the necessity or desirability for purchasing the various parcels of land offered for sale by owners located in and near the Swift River Valley. A total of 32,200 acres has been included in these reports to date. Similar reports have been made relative to properties involved in other projects under charge of the Commission located outside the Swift River Valley.

Taking plans have been prepared covering all the land necessary for the construction of the Wachusett-Coldbrook Tunnel and for the pipe lines, pumping station and open channel of the Southern Sudbury Emergency Supply. Fifteen taking plans covering 140 parcels of land were required for the tunnel, of which fourteen have been filed, and fourteen taking plans covering fifty-nine parcels of

land were required for the Southern Sudbury Emergency Supply, all of which have been filed.

Preliminary studies have been made of highway and cemetery relocations to determine the amount of land required.

Contracts and Specifications. — Twelve contracts have been awarded during the year. These include one minor contract for aerial surveys and one for furnishing electric power; the remaining ten contracts are for construction and total approximately $1,100,000.

Six of these contracts, totalling $450,000, are for construction for the Southern Sudbury Emergency Supply, including four for pipe lines totalling approximately 37,000 feet in length, one for an open channel approximately 5,000 feet in length and one for a small pumping station.

The other four contracts, totalling $650,000, are for construction for the Ware River Supply. Three of these are for construction shafts for the Wachusett-Coldbrook Tunnel totalling approximately 2,600 feet in depth, and one for an electric transmission line along the tunnel line for furnishing power needed for construction of the shafts and tunnel.

The required contract drawings and specifications have been prepared for these twelve contracts and working drawings have been issued from time to time as the work has progressed. Plans and specifications were also prepared for the proposed tunnel contracts for construction of the Wachusett-Coldbrook Tunnel from the Wachusett Reservoir to the Ware River at Coldbrook. The forms for these contracts were completed and the work advertised for bids which were opened on November 18, 1927.

Inspection and Tests. — Arrangements were made with Messrs. Skinner, Sherman & Esselen, Inc., Chemists and Engineers of Boston, for the testing of cement used on various contracts. Samples were at first taken from each car upon receipt at the work and shipped to their laboratory. Later arrangements were made for the sampling of each car at the cement mill at the time of shipment, these samples also being shipped immediately to their laboratory. Under these arrangements approximately 6,500 barrels of cement have been tested for the tunnel shaft linings under Contracts 4, 8 and 12. Approximately 500 barrels for these contracts were inspected and tested at the mill by E. L. Conwell & Company of Philadelphia.

Messrs. Conard & Buzby of Burlington, New Jersey, were employed to make mill inspection and tests of concrete pipe furnished by the Lock Joint Pipe Company under Contract 5, and cast iron pipe and valves furnished under Contracts 5, 6, 7, 11 and 13 for the Southern Sudbury Emergency Supply. Under these arrangements about 8,700 linear feet of 30″ concrete pipe have been inspected and tested, and 3,400 tons of cast iron pipe, sizes 12″, 18″, 20″ and 24″.

Tests of sand, brick and several small quantities of cement for various parts of the work have also been made by Skinner, Sherman & Esselen, Inc.

Aerial Surveys. — Work was continued, under the direction of the Headquarters Office, on Contract 3, with the Fairchild Aerial Surveys, Inc., for furnishing photographs obtained from aerial surveys of the entire Swift River Valley. The snow covered the ground before the west branch of the river had been photographed, necessitating the postponement of this work until spring.

The direct contact prints on a scale of approximately 1 inch equals 1,200 feet were found extremely useful to the field office in locating real estate boundaries and other physical features. It had been expected that enlargements to a scale of 1 inch equals 400 feet would prove even more valuable, but on account of the great differences in elevation of ground surface encountered it was not found practicable to obtain these enlargements to a sufficiently accurate scale. The usefulness of the smaller contact prints, however, more than justified this method of obtaining rapid surveys.

Contract 9, for aerial surveys along the Chicopee and Ware Rivers, was made with the Fairchild Aerial Surveys, Inc., on March 30, 1927, and the photography was promptly completed. Contact prints covering the entire distance from Chicopee to Coldbrook have been received together with enlarged prints of selected areas.

Index maps have been made of the contact prints obtained from these surveys.

They cover the entire length of the east, west and middle branches of the Swift River above Three Rivers, the Chicopee River from Chicopee to Three Rivers, and the Ware River from Three Rivers to Coldbrook.

Hydrographic Data. — A careful study of available data bearing on the flow of the Swift, Ware and Chicopee Rivers and on the rainfall upon their drainage areas has been made. Existing stream gaging stations and rain gages have been visited to determine what additional stream gaging stations may be desirable. The streams and watersheds have been reconnoitered to determine the most practical locations for such additional hydrographic stations. Stream gaging and other hydrographic work will, it is expected, be done in co-operation with the U. S. Geological Survey. One gaging station is already in process of construction on the Ware River at Coldbrook just below the proposed point of diversion into the tunnel at Shaft 8.

Considerable hydraulic field work has been done at the Boston Duck Mills of the Otis Company at Bondsville on the Swift River. The water power plant has been rated and other flow determinations have been made so that the stream will be continually gaged and the flow of the river in the past may be computed from existing records of plant operation.

For several days following the unusual flood that extended over the New England area early in November, 1927, various flood and flow measurements were made, in co-operation with the Hardwick office, on the Ware, Swift and Chicopee Rivers. Flood heights on all three rivers were recorded, and stream gagings were made on the Swift River at Bondsville and on the Ware River at White Valley just below Coldbrook.

Design of Structures

Tunnel Profile. — Gradient studies of the proposed Wachusett-Swift Tunnel have been made to fix the average slope of the tunnel and elevations of the invert at certain critical points. The general slope is downward from west to east, the grade line capacity being figured from a minimum draw-down to Elevation 435 in the Swift River Reservoir to the flow line of the Wachusett Reservoir at Elevation 395.

To facilitate drainage during construction each heading extending easterly from its construction shaft, instead of sloping downward, will be continued level until it meets the up grade extended westerly from the adjoining shaft. The tunnel will be level for the entire distance between Shafts 7 and 8 to assist the removal at Shaft 7 of air which will be unavoidably taken into the tunnel with the Ware River floods at Shaft 8 at Coldbrook.

At the east end of the tunnel at Shafts 1 and 2, sub-surface investigations showed that in order to insure an adequate depth of sound rock above the tunnel arch, the grade of the tunnel would have to be lowered about 200 feet more than requirements of the hydraulic gradient would indicate. The tunnel can then be operated under pressure with suitable control gates at the Wachusett end so that whenever desired the entire flood flow of the Ware River can be diverted westerly for storage in the Swift River Reservoir.

Tunnel Sections. — The tunnel will be lined with unreinforced concrete and will have a cross-section area equivalent to that of a circle 12′ 9″ in diameter. This will provide a combined carrying capacity of approximately 2,800 cubic feet per second for the flood flows of the Ware River at Coldbrook to the Wachusett Reservoir and to the proposed Swift River Reservoir. Until the tunnel is extended beyond Coldbrook, the carrying capacity to the Wachusett Reservoir only will be about half this quantity.

Two typical tunnel sections have been designed; one of the horseshoe type which will be used in sound rock and which will undoubtedly form the greater part, if not the entire length, of the completed tunnel; and one circular to be used where the rock is of poor quality and has a tendency to slip and bring excessive pressure against the tunnel lining. Each type includes a design where no support of the rock roof is required during construction, one where temporary support only is required and one where permanent support is required.

Although the ground water will probably be above the hydraulic gradient at all points practically all of the time, the concrete lining has not been designed to

resist the external hydrostatic pressure, but this pressure will be vented through weepers in the lining.

Construction Shafts. — In order to accomplish the diversion of the Ware River flood flows in 1931 and relieve any shortage of the water supply of the District which may occur before that date the construction of the Wachusett-Coldbrook Tunnel has been designed to be carried on by headings from eight shafts as follows: Shaft 1, 205 feet deep, the outlet into Wachusett Reservoir at the Quinapoxet River basin near Oakdale; Shaft 8, 253 feet deep, the intake on the Ware River near Coldbrook; and for construction purposes six construction shafts varying from about 8,800 feet to 11,600 feet apart and from 313 to 656 feet deep. The construction shafts will have permanent unreinforced concrete linings 14′ 0″ in diameter.

It was desired to locate the top of Shaft 2 slightly above the future level of the Swift River Reservoir and as near to the Quinapoxet River as possible in order that water from that river might at some future time be diverted through the tunnel to increase the amount of water power available for development at Shaft 1, when and if the power plant installation will have been made there. Investigations by borings indicated, however, that it would be necessary to locate the shaft at a higher level and at some distance from the river in order to strike sound rock near the surface without having to sink the shaft to any great depth in water-bearing earth. The designs have made provision, by suitable openings in the lining of Shaft 2, for the construction of future diversion works at such time as the value of the increased water power will justify the expense.

Shaft 1. Outlet to Wachusett Reservoir. — Four principal considerations in the design of Shaft 1 were the outlet from the tunnel into the Wachusett Reservoir, the measurement of flow through the tunnel, provision for a future water power development and also for unwatering the tunnel.

As designed, the outlet will consist of two horizontal openings at the shaft head discharging into a short open channel which will take the water into one of the upper branches of the Wachusett Reservoir at the Quinapoxet River basin. The retaining walls for the outlet channel are to serve as a foundation for a future hydroelectric power station. The installation of the generating equipment will be delayed because no water power will be available until there is adequate storage in the Swift River Reservoir, but the power house may be built in the near future to provide housing for cranes, pumps and miscellaneous equipment required in the tunnel operation. One of the horizontal openings will be used for the future penstock connection and the other for a blow-off.

The designs provide for the measurement of the entire discharge from the tunnel into the reservoir, by two Venturi meters, one for high flows and the other for low flows. The larger one will be vertical and cast in the concrete lining of the shaft. This meter with a ninety-inch throat will measure flows up to the maximum capacity of the tunnel for diverting flood flows easterly from the Ware River directly into Wachusett Reservoir, namely about 1,500 cubic feet per second. The smaller meter, of thirty-six inch throat diameter, will be installed in the outlet channel in a horizontal position. This meter will measure flows ranging from the minimum capacity which the large meter is capable of measuring accurately down to the lowest anticipated rates of diversion from the Ware River and the East and Middle Branches of the Swift River until the Swift River Reservoir is ready for storage. This thirty-six inch meter will be of a temporary nature and will be dismantled when the Swift River Reservoir is completed and the power equipment installed at Shaft 1.

On account of the necessity for lowering the grade of the tunnel at its east end to ensure support in sound rock, the volume of water in the tunnel below Elevation 390, *i.e.*, low water in the outlet channel, will be approximately 21,000,000 gallons, and provision must be made for handling this amount, plus any leakage into the entire tunnel, by emergency pumping equipment when it is desired to unwater this portion of the tunnel for inspection or repairs.

Several methods were considered but the final decision was to build in addition to the main outlet at Shaft 1 an additional pump shaft or well of equal depth but of smaller diameter. This second shaft will be pumped out by a small pump,

then a centrifugal pump and motor will be lowered to the bottom and connected up for pumping out the tunnel.

The entire Shaft 1 will be excavated and lined initially as a single shaft and used in that form during the work of excavating and lining the tunnel. Upon the completion of this work the partition separating the main outlet shaft and the smaller pump shaft will be installed, the pump shaft having a steel interlining to insure watertightness.

Shaft 8. Ware River Diversion Works. — The Ware River intake to the tunnel will consist of Shaft 8 and the diversion control works at the surface. Four principal considerations in the design were the diversion of the flood flows above the prescribed limit of 85 million gallons daily, the measurement of the quantity diverted and that left in the stream, the exclusion of air so far as possible from the water taken into the tunnel and the dissipation of the energy due to the drop in the shaft, the tunnel invert being approximately 260 feet below the level of the river.

Various methods of diverting and measuring the flow have been studied and good progress has been made in the details of the design. The general plan is to divert the water through several siphon spillways of various capacities which will insure the complete diversion above the prescribed limit and prevent any diversion below this limit. These spillways will discharge into a large well directly over the shaft. From this well the fall into the shaft will be controlled by four large butterfly valves automatically maintaining a water seal for the exclusion of air and insuring the submergence of a Venturi meter set vertically over one of the valves. This meter will measure the amount diverted under all ordinary conditions up to its capacity of approximately 700 million gallons daily. For extreme floods in excess of this amount the quantity may be estimated from measurements at other points.

The water will be discharged into the shaft at a point about 200 feet above the tunnel. Several different methods of dissipating the energy were studied. Theoretical investigations led to the conclusion that water discharged tangentially against the side of the shaft at an angle with the vertical would, by virtue of its centrifugal force, keep to the outside of the shaft and maintain a smooth fall in a helical path with minimum impact. Also, that if helical guides were constructed on the inside of the shaft lining they would maintain the circular motion of the water and preserve its centrifugal force, and cause the water to reach the bottom of the shaft in the form of a thin sheet pressing firmly against the shaft lining, the thin sheet dissipating its energy in an adequate depth of water at the bottom of the shaft. It has been decided to line Shaft 8 with cast iron as a further precaution against deterioration of the concrete under the high velocity and possible impact of the fall of water into the shaft.

Because of the importance attached to this principle in the design of the shaft lining, tests, under the direction of Professor Charles M. Allen, have been made on a 1/20 scale model at the Alden Hydraulic Laboratory of the Worcester Polytechnic Institute. The tests were made to cover the entire range of operating conditions and to show the effect of various forms of guides cast in the lining of the shaft.

The shaft will be excavated and lined initially with concrete and used in that form during the excavation and lining of the tunnel. When completed the shaft will be lined with cast iron and the results of the laboratory tests on the model are being used in determining the form of the castings which will make up the finished lining.

Sanitary Precautions in Wachusett Watershed. — Special sanitary precautions will be taken during the construction operations at Shafts 1 to 4 inclusive, which are located within the drainage area tributary to the Wachusett Reservoir, and particularly at Shafts 1 and 2, which are close to this present source of water supply. The specifications which have been prepared covering the construction of the tunnel from these shafts require extreme care in the control of the contractor's employees, the inspection of camps and the treatment of all wastes and drainage. The designs for sanitary works at these shafts include drains, settling basins and suitable provision for chlorination of all surface drainage. Further-

more, at Shafts 1 and 2 designs have been prepared for slow sand filters to take care of the drainage and insure against any contamination of the existing water supply.

Diversion Works for Southern Sudbury Emergency Supply. — Chapter 111, Acts of 1927, authorized the development of the Southern Sudbury Emergency Supply by diverting into the main Sudbury Reservoir, or directly into the Sudbury Aqueduct, the waters from selected areas at the headwaters of the Southern Sudbury watershed, which would have a sufficiently low color and satisfactory quality for mixing with the present supply without filtration.

Designs were made which involved three separate pipe lines, a pumping station, an open channel and appurtenant structures as follows:

1. A gravity flow 24-inch pipe line from the Ashland Reservoir of the District to the gate house at Framingham Reservoir No. 2 which is connected by an existing 48″ cast iron main to the gate house at Framingham Reservoir No. 1 at the head of the Sudbury Aqueduct.

2. A gravity flow 20-inch pipe line from the Whitehall Reservoir of the District to a point where City Brook, a small tributary of the brook flowing from Whitehall Reservoir, crosses City Road or Proctor Street, in the town of Hopkinton. Also a small diversion dam and reservoir at this point and an open channel to divert the entire natural flow tributary to the diversion reservoir as well as the discharge from the pipe line over the divide into the Hopkinton Reservoir of the District.

3. A gravity flow 30-inch pipe line from the Hopkinton Reservoir of the District across the Sudbury River near Cordaville and over the divide into the upper reaches of the main Sudbury Reservoir of the District. Also a pumping station at Cordaville, containing a two hundred fifty horse power motor-driven centrifugal pump, and a branch line to an intake at the mill pond of the Cordaville Woolen Company, so that the pipe line to the Sudbury Reservoir can take either the gravity flow from the Hopkinton Reservoir or the pump discharge from the Sudbury River at Cordaville. The pump can also be used as a booster in the gravity line from the Hopkinton Reservoir.

On account of the urgent need of this emergency supply for the District, the field reconnaissance and surveys were rushed to early completion, taking plans prepared for the necessary land and rights of way, and the entire construction carried to practical completion within the year. The specifications were prepared calling for bids on either cast iron Class A (American Water Works Association) or reinforced concrete pipe in the case of the thirty-inch line from Hopkinton Reservoir and the twenty-four inch line from Ashland Reservoir. For the smaller twenty-inch line from Whitehall Reservoir cast iron pipe Class A was specified.

The flow through the Hopkinton line into the Sudbury Reservoir will be measured by a 30″ x 15″ Venturi meter in the pumping station and the flow through the Ashland pipe line into the Sudbury Aqueduct will be measured by a 20″ x 10″ Venturi meter located at the Ashland Dam. The flow through the Whitehall pipe line can be rated by a weir at its outlet.

Surveys and studies were made to determine the feasibility of constructing a decolorizing plant at the outlet of the Hopkinton line into the Sudbury Reservoir. The outlet well at the end of the pipe line is designed so that it may, if required, serve the purpose of a mixing chamber.

Chlorinating apparatus installed in the pumping station at Cordaville will allow chlorination as required of either the pumpage from the Cordaville Woolen Company's mill pond or the gravity flow from the Hopkinton Reservoir. Similar chlorinating apparatus installed in the District's Framingham Gate House No. 1 will allow chlorination as required of the flow from Ashland Reservoir.

The following tabulation shows briefly the sources and extent of the additions to the supply of the District which have been made in the Southern Sudbury area:

	Drainage Area (Square Miles)	Pipe Line			
		Length (Feet)	Diameter (Inches)	Material	Capacity (M.G.D.)
Ashland Reservoir	6.43	–	–	–	–
Ashland to Framingham Res. No. 2	–	14,400 [1]	24	C. I.	9
Total above Ashland Reservoir	6.43	–	–	–	–
Whitehall Reservoir	4.35	–	–	–	–
Whitehall to City Road	–	6,740	20	C. I.	6.5
City Road Diversion Reservoir	0.40	–	–	–	–
Hopkinton Reservoir	5.86	–	–	–	–
Hopkinton to Cordaville	–	7,000	30	C. I.	14
Cordaville to Sudbury Reservoir	–	8,130	30	Con.	
Total above Hopkinton Reservoir	10.61	–	–	–	–
Additional above Cordaville Intake	17.24	–	–	–	–
Branch from Cordaville Intake	–	945	30	Con.	21 [2]

[1] Includes approximately 980 feet of 20-inch cast iron pipe.
[2] Pumped.

Holden Office, Wachusett-Coldbrook Tunnel Division

The Wachusett-Coldbrook Tunnel Division office at Holden Center has had charge of the field work in connection with the Wachusett-Coldbrook Tunnel, and, during the greater part of the year until the Hardwick Office was established, the surveys and borings in connection with the Coldbrook-Swift Tunnel extension. This division has continued in charge of the borings along the entire tunnel line, but the surveys for the extension beyond Coldbrook have been taken over by the Coldbrook-Swift Tunnel Division, established in September. The latter Division has also taken over the direction of work at the site of Shaft 8.

Office Work

Traverse lines have been calculated and co-ordinates of the traverse points figured. Topography notes have been reduced and plotted, and contour maps drawn for each shaft site. Property calculations have been made and property plans of the properties along the tunnel line and at the shaft sites sent to the Headquarters Office for the preparation of taking plans. All survey data has been co-ordinated on the basis of the existing Wachusett system of rectangular co-ordinates with 50,000 added to the eastings.

Shaft cross-sections showing the progress of construction have been plotted and measured. Monthly estimates have been made for Contracts 1, 4, 8, 10 and 12.

Field Work

Taped traverse lines were run along the Central Massachusetts Railroad and the highways for a total distance of 33 miles to locate the shafts for the Wachusett-Coldbrook Tunnel, and a taped traverse of 28 miles was run to locate the shafts for the Coldbrook-Swift Tunnel extension. Topography was taken at the eight shaft sites on the Wachusett-Coldbrook Tunnel to determine the areas required for camp sites and for the extensive spoil banks required for disposal of the rock to be excavated from the tunnel. Detailed topography was taken at the sites for Shafts 1, 2, 3 and 4 to obtain information for studies for filtration and chlorination works for treating the drainage from the tunnel and camps. The center line of the tunnel between Shafts 1 and 8 was cut through and taped by precise methods, a distance of 13.2 miles, and a surface profile taken. Property surveys were made for takings of camp sites and spoil areas at the shafts and for a taking, 50 feet wide, along the center line of the tunnel.

In April, 1927, an agreement was reached with the United States Department of Commerce, Coast and Geodetic Survey, for co-operative effort in running a line of precise levels from Springfield to Boston. This increased the primary net work of the survey in this vicinity and also furnished the Commission the necessary

benches along the Chicopee and Ware Rivers and in the vicinity of the tunnel line between the Wachusett Reservoir and Coldbrook.

Later, lines of precise levels were extended to each shaft site on the Wachusett-Coldbrook Tunnel. These levels were also continued to the location of shafts on the Coldbrook-Swift Tunnel extension. In the Swift River Valley also, precise levels were run for 155 miles and 92 bench marks set, under the direction of the Holden Office.

Surveys were made of the White Bros. mill property at Coldbrook, of the Rutland Worsted Co. mill property at West Rutland and of various other properties. Diamond drill borings for the subsurface investigations of the tunnel line were located and elevations of the ground surface taken at each boring. Lines and grades were given for construction work on Contracts 4, 8, and 12. Sixty stone bounds were set at property corners.

Progress of Contracts

Contract 1. — Contract 1 with the Pennsylvania Drilling Co., Pittsburgh, Pa., for borings along the line of the tunnel was continued until July 15, 1927, when a final estimate was made. Work done under this contract was as follows:

	Number of holes	Depth to Ledge	Depth in Ledge
Year ending Nov. 30, 1926	1	70.0	16.0
Year ending Nov. 30, 1927	63	3,097.8	1,570.5
Total	64	3,167.8	1,586.5

Of these 64 holes, 39 were for determining the location of the Wachusett-Coldbrook Tunnel and the construction shafts and 25 for the Coldbrook-Swift Tunnel extension.

The original estimate of quantities on the basis of which the contract was let in November, 1926, was approximate only and merely for the purpose of securing unit prices for the work. The extent of the subsurface investigations which would be required was not known at that time. The amount of work actually required from the contractor at these unit prices was more than double the amount of the original estimate. Still further work in scattered locations remained to be done and on July 15 a supplementary agreement was made with the Pennsylvania Drilling Company to continue core borings to the surface of sound bed rock at $4.50 per foot, and core borings in sound bed rock at $5.50 per foot. Under this agreement 31 holes have been drilled to date with a total depth to ledge of 1,969.7 feet and a total depth in ledge of 468.5 feet. Practically all these holes were required to determine a suitable location for the Coldbrook-Swift Tunnel extension.

The subsurface investigations revealed the fact that the rock bed of the Ware River drops from a point near the surface at the site of the diversion dam and Shaft 8 to an elevation over 200 feet lower and more than 160 feet below the surface at a point near Barre Plains. This fact made it necessary to thoroughly investigate the possibility of a deep rock gorge underlying the Prince River, a tributary of the Ware River from the north, and to locate the line of the tunnel further north than was originally planned. A sufficient number of borings, it is believed, have been completed along the line finally selected to insure an adequate cover of sound bed rock at the crossing of Prince River, Muddy Brook and all other points where the possibility of a deep glacial gorge in the bed rock appeared.

Gasoline driven drilling machines were used on this work. The average number of men employed was 1 operator and 2 laborers for each machine.

Contract 4. Contract 4, for sinking Shaft 5 for the Wachusett-Coldbrook Tunnel in the Town of Rutland, was awarded to James J. Coughlan & Sons, Inc., Boston, Massachusetts, on March 28, 1927. The first construction work consisted of grading at the shaft site and clearing for the camp. Timbering was not required during earth excavation but was placed after rock excavation was started. Wooden forms, made in four sections to the circle and 5 feet high, were used for the concrete lining. On November 30 excavation was in progress at the bottom of the shaft and had been completed to 8 feet above the tunnel invert.

Miscellaneous construction data:

	Shaft 5
Total depth of shaft	656 ft.
Depth of earth	19 ft.
Depth of rock	637 ft.
Contract awarded	March 28, 1927
Work begun	April 4, 1927
Earth excavation completed	May 7, 1927
Rock excavation begun	May 11, 1927
First concrete lining placed	July 5, 1927
Concrete lining completed	Nov. 26, 1927
Average weekly progress of excavation and concrete lining	19.8 ft.
Maximum depth of rock excavated in one week	47 ft.
Maximum weekly average pumpage (after sinking 300 ft.)	32 g.p.m.
Minimum weekly average pumpage (after sinking 300 ft.)	20 g.p.m.
Average number of men employed per day in two shifts	39

The plant equipment at Shaft 5 consisted of the following:

2 W. J. 3 Sullivan Compressors, 14″x 8¾″, delivering a total of 1,060 cu. ft. of air per min. with 2 Gen. Elec. 100 H. P. Motors.
1 Air Receiver Tank, 10′-0″x 3′-6″ diam.
1 Lidgerwood 1-drum Electric Hoist with Gen. Elec. 50 H. P. Motor. (This was transferred to Shaft 6 on Sept. 7, when a Flory 1-drum Electric Hoist with Gen. Elec. 75 H. P. Motor was installed.)
1 Ransome ½-yd. Concrete Mixer with Gen. Elec. 7½ H. P. Motor.
1 Reliance Stone Crusher and screen with Ridler 15 H. P. Motor.
1 Drill-sharpening Machine.
1 Oil Furnace with 5 H. P. Motor.
On May 24 a 40 ft. Wooden Head-frame was erected.

The following is a summary of the work done and materials furnished under the principal items of the contract during the year:

	Shaft 5
Earth excavation	177.2 cu. yds.
Rock excavation in shaft and tunnel	5,026. cu. yds.
Drainage in shaft	324. lin. ft.
Forms for shaft lining	633. lin. ft.
Concrete shaft lining	1,429. cu. yds.
Portland cement	1,754. bbls.

Contract 8. — Contract 8, for sinking Shafts 6 and 7 for the Wachusett-Coldbrook Tunnel in the Town of Rutland, was awarded to James J. Coughlan & Sons, Inc., Boston, Massachusetts, on May 24, 1927. The earth section in each shaft was timbered with 8″ x 8″ sets and 2″ lagging. Wooden forms for the concrete lining were used as at Shaft 5, Contract 4. On November 30 Shaft 6 had been excavated to 6 feet above the tunnel invert, and at Shaft 7 the tunnel had been excavated 123 feet towards Shaft 6 and 128 feet towards Shaft 8.

Miscellaneous construction data:

	Shaft 6	Shaft 7
Total depth of shaft	432 ft.	411 ft.
Depth of earth	29 ft.	25 ft.
Depth of rock	403 ft.	386 ft.
Contract awarded	May 24, 1927	May 24, 1927
Work begun	June 1, 1927	June 1, 1927
Earth excavation completed	July 9, 1927	June 25, 1927
Rock excavation begun	July 12, 1927	June 30, 1927
First concrete lining placed	Aug. 9, 1927	July 25, 1927
Concrete lining completed	Nov. 23, 1927	Oct. 25, 1927
Average weekly progress of excavation and concrete lining	16.5 ft.	18.6 ft.
Maximum depth of rock excavated in one week	35 ft.	35 ft.
Maximum weekly average pumpage (after sinking 150 ft.)	4 g. p. m.	15 g. p. m.
Minimum weekly average pumpage (after sinking 150 ft.)	0 g. p. m.	2 g. p. m.
Average number of men employed per day in two shifts	31	35

The plant equipment at Shaft 6 consisted of the following:

1 Stiff-legged Derrick with 40 ft. Boom.
1 Mead-Morrison 2-drum Steam Hoist with 25 H. P. Boiler.
2 Sullivan Compressors delivering 233 and 530 cu. ft. of air per min. with Westinghouse 50 and 100 H. P. Motors.
1 Ingersoll-Rand Gasoline Portable Compressor delivering 150 cu. ft. of air per min.
1 Air Receiver Tank, 10′–0″ x 3′–6″ diam.
1 Ransome ½-yd. Concrete Mixer.
On Sept. 7 a Wooden Head-frame was erected and the Lidgerwood Electric Hoist from Shaft 5 was installed.

The plant equipment at Shaft 7 consisted of the following:

1 Stiff-legged Derrick with 60 ft. Boom.
1 Mead-Morrison 2-drum Steam Hoist with 25 H. P. Boiler.
2 Sullivan Compressors delivering 233 and 530 cu. ft. of air per min. with Westinghouse 50 and 100 H. P. Motors.
1 Gasoline Portable Compressor delivering 220 cu. ft. of air per min.
1 Air Receiver Tank, 10′–0″ x 3′–6″ diam.
1 Rex Gasoline ½-yd. Concrete Mixer.
On August 10 a Wooden Head-frame was erected and the Steam Hoist replaced by a Flory 1-drum Electric Hoist with 50 H. P. Motor.

The following is a summary of the work done and materials furnished under the principal items of the contract during the year:

	Shaft 6	Shaft 7
Earth excavation	273.3 cu. yds.	230.9 cu. yds.
Rock excavation in shaft and tunnel	3,174. cu. yds.	4,769. cu. yds.
Drainage in shaft and tunnel	211. lin. ft.	324. lin. ft.
Forms for concrete lining	413. lin. ft.	392. lin. ft.
Concrete shaft lining	960. cu. yds.	908. cu. yds.
Portland cement	1,054. bbls.	1,105. bbls.

Contract 10. — Contract 10, for constructing, maintaining and operating a 22,000-Volt Transmission Line in the Towns of West Boylston, Holden, Rutland, Oakham and Barre, was made with the New England Power Company, Worcester, Mass., on April 27, 1927. This line extends from West Boylston to Shaft 1 and from there generally over the tunnel line to Shaft 8. A transformer sub-station was constructed at the connection to the Power Company's 66,000 volt line in West Boylston.

Work was started immediately on clearing for the transmission line which was built, from West Boylston to Shaft 2, on property of the Commonwealth. From Shaft 2 to Shaft 8, the line was over the 50-ft. taking on the center line of the tunnel, which was cleared for the full width of 50 feet. A three-wire transmission line was erected on wooden poles from 35 to 40 feet in height. The work was performed with all possible speed and was completed, with the line energized, on June 20.

The average number of men employed per day was 69.

Contract 12. — Contract 12, for sinking Shafts 2, 3 and 4 for the Wachusett-Coldbrook Tunnel in the Towns of Holden and Rutland, was awarded to the Dravo Contracting Co., Pittsburgh, Pa., on May 24, 1927. The earth sections at Shafts 2 and 4 were timbered with 8″ x 8″ sets spaced 5 feet apart and 2″ lagging. At Shaft 3 a reinforced concrete caisson was sunk to ledge. This caisson was 14.5 feet inside diameter, with a thickness of 32″, and was built in 8-foot sections. The bottom section was equipped with a steel shoe for a cutting edge. Wooden forms were used for the concrete lining.

A modification of Contract 12 was made October 25, 1927, with the Dravo Contracting Co. authorizing, at a modified price, tunnel excavation by the Contractor beyond the limits set by the original contract.

On November 30 the tunnel at Shaft 2 had been excavated 213 feet towards Shaft 1 and 230 feet towards Shaft 3. At Shaft 3 excavation had been completed to 4 feet above the tunnel invert, and at Shaft 4 excavation had been completed to 17 feet above the tunnel invert.

Miscellaneous construction data:

	Shaft 2	Shaft 3	Shaft 4
Total depth of shaft	313 ft.	339 ft.	457 ft.
Depth of earth	25 ft.	61 ft.	23 ft.
Depth of rock	288 ft.	278 ft.	434 ft.
Contract awarded	May 24, 1927	May 24, 1927	May 24, 1927
Work begun	June 14, 1927	June 8, 1927	June 8, 1927
Earth excavation completed	July 1, 1927	Aug. 18, 1927	July 9, 1927
First section of caisson poured		July 20, 1927	
Concrete caisson completed		Aug. 18, 1927	
Rock excavation begun	July 1, 1927	Aug. 18, 1927	July 9, 1927
First concrete lining placed	July 15, 1927		July 25, 1927
Concrete lining completed	Sept. 22, 1927	Nov. 12, 1927	Nov. 30, 1927
Average weekly progress of excavation and concrete lining	21.1 ft.	19.2 ft.	19.2 ft.
Maximum depth of rock excavated in one week	41 ft.	40 ft.	31 ft.

	Shaft 2	Shaft 3	Shaft 4
Maximum average weekly pumpage (after sinking 100 ft.)	10 g. p. m.	8 g. p. m.	100 g. p. m.
Minimum average weekly pumpage (after sinking 100 ft.)	10 g. p. m.	0 g. p. m.	60 g. p. m.
Average number of men employed per day in two shifts	35	24	37

The plant equipment at Shaft 2 consisted of the following:

1 Steel Stiff-legged Derrick with a 50 ft. Boom.
1 Lambert 2-drum Electric Hoist with Swinging Engine and a Westinghouse 82 H. P. Motor.
2 Ingersoll-Rand Air Compressors delivering 446 and 528 cu. ft. of air per min. with Gen. Elec. 104 and 100 H. P. Motors.
1 Air Receiver Tank, 11′–0″ x 4′–0″ diam.
1 Lakewood ¾-yd. Concrete Mixer with an Allis-Chalmers 15 H. P. Motor.

The plant equipment at Shaft 3 consisted of the following:

1 Lambert 3-drum Hoist with Swinging Engine run by compressed air.
1 Lambert 1-drum Electric Mine Hoist with Westinghouse 100 H. P. Motor.
2 Ingersoll-Rand Compressors delivering 446 and 324 cu. ft. of air per min. with Gen. Elec. 75 and 50 H. P. Motors.
1 Air Receiver Tank, 8′–0″ x 3′–0″ diam.
1 Koehring ¾-yd. Concrete Mixer with Westinghouse 15 H. P. Motor.
1 Steel Stiff-legged Derrick with 45 ft. Boom and a 34 ft. Steel Head-frame.

The plant equipment at Shaft 4 consisted of the following:

1 Lambert 2-drum Steam Hoist with 50 H. P. Steam Boiler.
1 Thomas Elevator Co. 2-drum Electric Hoist with a Wagner 90 H. P. Motor.
2 Ingersoll-Rand Compressors delivering 546 and 324 cu. ft. of air per min. with Westinghouse 60 and 100 H. P. Motors.
1 Air Receiver Tank, 10′–4″ x 5′–0″ diam.
1 Marsh-Capron ¾-yd. Concrete Mixer.
1 Drill Sharpening Machine.
1 Oil Furnace.
1 Stiff-legged Derrick with 45 ft. Boom which was used with the Steam Hoist until the Shaft reached a depth of 65 ft. Then a 40 ft. Wooden Head-frame was erected and the Electric Hoist used.

The following is a summary of the work done and materials furnished under the principal items of the contract during the year:

	Shaft 2	Shaft 3	Shaft 4
Earth excavation	231.8 cu. yds.	693.4 cu. yds.	214.9 cu. yds.
Rock excavation in shaft and tunnel	5,329. cu. yds.	2,394. cu. yds.	3,316. cu. yds.
Drainage in shaft and tunnel	369. lin. ft.	166. lin. ft.	220. lin. ft.
Forms for concrete lining	291.1 lin. ft.	327. lin. ft.	441. lin. ft.
Concrete shaft lining	682.8 cu. yds.	956. cu. yds.	1,022. cu. yds.
Portland cement	920. bbls.	1,258. bbls.	1,414. bbls.
Chlorine	–	–	35 lbs.
Chlorine dosing machine	1	1	1
Drilling holes in rock	–	–	364 ft.
Grout	–	–	14 cu. yds.

Hardwick Office, Coldbrook-Swift Tunnel Division

The Coldbrook-Swift Tunnel Division office at Hardwick was established in September, 1927. It has taken over the direction of surveys in connection with the proposed Coldbrook-Swift Tunnel extension, including the site of Shaft 8. The borings for the entire tunnel, however, have remained under the direction of the Wachusett-Coldbrook Tunnel Division office at Holden.

Office Work

Topography notes have been reduced and plotted, traverses have been calculated, cross-sections in the vicinity of Shaft 8 have been plotted and deeds of properties along the proposed Coldbrook-Swift Tunnel extension line have been copied. A plan of the entire line from Shaft 8 to the Portal in the vicinity of East Pond in Greenwich on a scale of 1″ = 400′ was begun, and also plans of topography at the sites of Shafts 9, 10 and 11.

Field Work

Field work was started on September 20. Approximately 20 miles of stadia traverse lines were run and 70 acres of topography taken, including the sites of Shafts 9, 10 and 11 of the Coldbrook-Swift Tunnel extension. The approximate location of the center line of this tunnel was laid out as proposed when work on this Division was first started in September, and also the more northerly location

that was selected when the results of borings indicated that there would probably not be sufficient depth of sound rock cover for the tunnel in the location first selected. Field work for property takings was started.

Enfield Office, Swift River Reservoir Division

The Swift River Reservoir Division office at Enfield has had charge of the field work in the Swift River Valley in connection with the proposed Swift River Reservoir.

Office Work

Topography notes have been reduced and approximately 6,300 acres have been plotted to a scale of 1″=200′ on record mounted plans. Maps on a scale of 1″=400′ of the towns of Enfield, Greenwich, and Dana have been made showing the approximate ownership of lands in these towns. These maps were made with the assistance of the Assessors of the various towns for the purpose of aiding the title examiners of the Commission in the search of records. A general map of the area which may be affected by the Swift River Reservoir was prepared from existing maps and information obtained by aerial photographs on a scale of 1″=1,000′ for the purpose of showing property acquired by the Commission and from time to time such properties have been located on this map.

Computations have been made of the triangulation system and co-ordinates of all points figured on the rectangular co-ordinate system which was adopted for the area affected by the Swift River Reservoir and the tunnel as far east as Coldbrook. In this system the co-ordinate plane is tangent to the spheroid of the earth at the point whose latitude is N 42° 22′ 30″ and whose longitude is 72° 18′ 00″ west of Greenwich. The co-ordinate axes are straight lines tangent at this point to the meridian and a great circle at right angles to it. The rectangular co-ordinates of this tangent point are N 86,166.56 and E 98,807.57.

Field Work

A major triangulation control system based upon a base line measurement in the town of Greenwich and including the erection of permanent signals covering the area of all probable survey work for the Swift River Reservoir was completed on June 24, 1927.

Topographic surveys of the dam and dike sites were made, together with similar surveys of portions of the reservoir area, covering a total of approximately 11,500 acres or 18 square miles. About 4,200 acres of real estate were surveyed, a large part of which has been acquired by the Commission. Approximate location was made of property lines along that part of the Coldbrook-Swift Tunnel extension to be located within the area which may be affected by the Swift River Reservoir. Photographs of 98 buildings acquired by the Commission, or offered for sale to the Commission, were taken for record.

Permanent bench marks, connected by precise levels to those established by the Holden office in co-operation with the U. S. Coast and Geodetic Survey, were established throughout the Swift River Valley for control of all topographic work.

A census was made of burials in all cemeteries which may be affected by the Swift River Reservoir. The work of copying inscriptions and locating each headstone or monument has been partially completed.

Surveys were made for the proposed temporary diversion dam below Greenwich Lake. The Sunk brook swamp area lying north of the Beaver Brook divide was sounded and a possible high water line resulting from the flowage which may be caused by the temporary diversion dam was located.

This Division co-operated with the Holden office in supervision of borings under Contract 1, with the Pennsylvania Drilling Co., in the exploration of possible tunnel portal sites on the westerly end of the Coldbrook-Swift Tunnel extension at the Swift River Reservoir.

Progress of Contracts

Contract 2.— Contract 2, for borings at the proposed dam and dike sites, was completed and a final estimate made on June 3, 1927. A total of 58 holes were drilled of which 26 were for determining the location and character of bed rock

and overlying material at the site of the dike and 32 were for the main dam. The total depth drilled was 6,180.6 feet, of which 5,050.8 feet were in overburden and 1,129.8 feet in bedrock.

Framingham Office, Southern Sudbury Emergency Supply

The Southern Sudbury Emergency Supply office at Framingham has had charge of the field work in connection with the preliminary surveys, final location and construction of the various projects required for the diversion of water from the headwaters of the Southern Sudbury drainage area directly into the Sudbury Reservoir or the Sudbury Aqueduct.

Office Work

Much preliminary information was obtained from plans of the original Boston Water Works on file in the office of the Metropolitan District Commission. Topography notes were reduced and plotted. Plans of the properties required along the pipe lines and for other structures were sent to the Headquarters office for the preparation of taking plans. Monthly estimates were made for Contracts 5, 6, 7, 11, 13 and 16.

Field Work

About 18 miles of levels were run to establish benches for use in taking topography and running profiles for the various pipe lines. Most of the topography, as well as the preliminary traverse lines, was surveyed by stadia. Approximately 21.4 miles of stadia traverses were run and 780 acres of topography taken. Rod soundings were made and numerous test pits dug to determine the nature of the material to be encountered in excavation.

Progress of Contracts

Contract 5. — Contract 5, for constructing a 30-inch pipe line from Cordaville to Sudbury Reservoir in the Town of Southborough, was awarded to the Lock Joint Pipe Company, Ampere, New Jersey, on April 15, 1927. The award was made for reinforced concrete cylinder pipe. This pipe was manufactured at the Contractor's plant at Ampere, New Jersey, and shipped by rail to Cordaville. Most of the excavation was made by a Speeder gasoline shovel with a ½-yard ditcher bucket. A four-wheel laying rig was used where possible for placing the pipe, the remainder being placed by the Speeder shovel.

Miscellaneous construction data:

Length of line	9,000 ft.
Size of pipe	30 in.
Width of taking, main part of line	30 ft.
Contract awarded	April 15, 1927
Work begun	June 6, 1927
Average length of pipe laid per week	488 ft.
Maximum length of pipe laid per week	999 ft.
Leakage, from "Y" connection with Contract 7 to outlet, in gal. per day per in. diam. per mi. of pipe [1]	139.4
Test made	Oct. 7, 1927
Leakage, from intake to "Y" connection with Contract 7, in gal. per day per in. diam. per mi. of pipe	41.6
Test made	Nov. 22, 1927
Average number of men employed per day	20

The contract was nearly completed on November 30, 1927, and the following is a summary of the work done and materials furnished under the principal items of the contract during the year:

Furnishing and laying 30-inch concrete pipe	8,779 ft.
Furnishing and laying 18-inch cast iron pipe	220 ft.
Furnishing and laying 12-inch cast iron pipe	269 ft.
Earth excavation, fill and refill	8,980 cu. yds.
Rock excavation and refill	366 cu. yds.

Contract 6. — Contract 6, for constructing a pumping station in the Town of Southborough, was awarded to F. A. Mazzur Co. Inc., Boston, Mass., on May 2, 1927. Hand excavation for the foundation was started on May 26 and the con-

[1] Includes the leakage from the by-pass piping at the Cordaville Pumping Station, Contract 6, and the "Y" connection with Contract 7.

crete foundation was completed June 15. The 250-H. P. pumping unit, consisting of a 20″ Worthington Centrifugal Pump and a General Electric Motor, was installed on August 19.

The permanent power connection to the 2,200 volt line of the Marlborough Electric Company was made on October 15 and the acceptance test of the main pumping unit was run on October 18.

Chlorinating apparatus was furnished and installed by the Commission in the pumping station erected under Contract 6. The chlorinator pump did not deliver a uniform flow when first tested on October 6, nor in any subsequent tests, and a new pump of the same type but with air chambers was installed on November 11, and has performed satisfactorily.

Contract 7. — Contract 7, for constructing a 30-inch pipe line from Hopkinton Reservoir to Cordaville in the Towns of Ashland and Southborough, was awarded to Cenedella & Co., Milford, Mass., on May 4, 1927. The award was made for cast iron pipe. The pipe was shipped by rail from the Warren Foundry and delivered at the Cordaville Station. Practically all the trench excavation was made by two Erie steam shovels with ¾-yard buckets before any pipe was laid. These shovels were also used to place the pipe. Lead hydrotite was used in pouring the joints.

At the Sudbury River crossing it was necessary to bring in some selected material for backfill under and around the pipe. Lead joints were used for the pipe for the full length of the river crossing. The river was diverted during construction by a channel excavated about 100 feet west of the natural river bed.

Miscellaneous construction data:

Length of line	7,000 ft.
Size of pipe	30 in.
Width of taking	40 ft.
Contract awarded	May 4, 1927
Work begun	May 9, 1927
Average length of pipe laid per week	634 ft.
Maximum length of pipe laid per week	1,793 ft.
Leakage in gal. per day per in. diam. per mi. of pipe	117.8
Test made	Sept. 28, 1927
Average number of men employed per day	22

The contract was nearly completed on November 30, 1927, and the following is a summary of the work done and materials furnished under the principal items of the contract during the year:

Furnishing and laying 30-inch cast iron pipe	6,977 ft.
Excavation	12,273 cu. yds.
Furnishing and placing paving	80 cu. yds.
Furnishing and placing riprap	267 cu. yds.
Furnishing and placing concrete	43 cu. yds.
Furnishing and placing 18-inch cast iron culvert pipe	120 ft.

Contract 11. — Contract 11, for constructing a 24-inch pipe line from Ashland Reservoir to gate house at Framingham Reservoir No. 2 in the Towns of Ashland and Framingham, was awarded to Antonio Mogavero, Peabody, Mass., June 3, 1927. The award was made for cast iron pipe. The excavation, laying of pipe and backfilling were each carried on continuously. The excavation and pipe laying was done by a ½-yard Bay City gasoline excavator and a considerable part of the backfill was done with a Fordson Tractor with two cables pulling material into the trench with hand scrapers. Lead hydrotite was used for the joints.

Framingham Reservoirs Nos. 1 and 2 were drawn down by the Metropolitan District Commission in order to facilitate the construction where the line crosses these reservoirs. Very little muck was found on the bottom of the Reservoir No. 2 at the lower crossing. This was removed for laying the pipe and levelled with gravel which was obtained in the basin. The upper crossing of Reservoir No. 2 was done when the water was very low and was carried on one-half at a time by means of sandbag cofferdams.

Miscellaneous construction data:

Length of line	14,400 ft.
Size of pipe	20 and 24 in.
Width of taking	40 ft.
Contract awarded	June 3, 1927

Work begun	June 6, 1927
Average length of 24″ pipe laid per week	790 ft.
Average length of 20″ pipe laid per week	192 ft.
Maximum length of 24″ pipe laid per week	1,418 ft.
Maximum length of 20″ pipe laid per week	622 ft.
Leakage in gal. per day per in. diam. per mi. of pipe	136.3
Test made	Nov. 29, 1927
Average number of men employed per day	28

This contract was nearly completed on November 30, 1927, and the following is a summary of the work done and the materials furnished under the principal items of the contract during the year:

Furnishing and laying 24″ cast iron pipe	13,439 ft.
Furnishing and laying 20″ cast iron pipe	967 ft.
Earth excavation, fill and refill	11,000 cu. yds.
Rock excavation and refill	631 cu. yds.
Furnishing and placing riprap	38 cu. yds.
Furnishing and placing concrete	70 cu. yds.

Contract 13. — Contract 13, for constructing a 20-inch pipe line from Whitehall Reservoir to a diversion dam on City Brook in the Town of Hopkinton, was awarded to the Portland Contracting Co. Inc., Portland, Maine, on July 15, 1927. The diversion dam was built first. The impervious core was obtained by stripping by hand the soil from the area north of the reservoir site and adjacent to the dam site. Pervious embankment was obtained from a borrow pit about 1,000 feet away and just off City Road.

Approximately 3,025 feet of trench was excavated by a ½-yard Bay City excavator, the remainder being done by hand except for rock excavation. An Ingersoll-Rand compressor with jack hammers was used for drilling the rock.

Miscellaneous construction data:

Length of line	6,740 ft.
Size of pipe	20 in.
Width of taking	40 ft.
Contract awarded	July 15, 1927
Work begun	July 25, 1927
Average length of pipe laid per week	438 ft.
Maximum length of pipe laid per week	1,265 ft.
Average number of men employed per day	24

This contract was nearly completed on November 30, 1927. There remained about 470 feet of pipe to be laid and some miscellaneous work to be done. The following is a summary of the work done and materials furnished under the principal items of the contract during the year:

Furnishing 20-inch cast iron pipe	6,660 ft.
Laying 20-inch cast iron pipe	6,350 ft.
Excavation, fill and refill	4,600 cu. yds.
Excavation at diversion dam	464 cu. yds.
Furnishing and placing impervious core and blanket at diversion dam	730 cu. yds.
Furnishing and placing pervious embankment	1,590 cu. yds.
Furnishing and placing soil dressing	159 cu. yds.
Furnishing and placing concrete	50 cu. yds.
Furnishing and placing paving	25 cu. yds.

Contract 16. — Contract 16, for clearing and excavating open channel from the reservoir formed by the diversion dam on City Brook to Hopkinton Reservoir in the Town of Hopkinton, was awarded to the Sanders Engineering Co., Portland, Maine, on September 23, 1927. The clearing was done in the usual way, a small amount of wood and timber being salvaged. The stumps in the grubbing operation were removed by pulling with a steam hoisting engine. Excavation for the channel was started at the lower end. A gasoline shovel with a one-yard drag line bucket was used. This shovel was carried on pontoons between the channel and a spoil bank on the north side of the channel.

Miscellaneous construction data:

Length of channel	5,000 ft.
Contract awarded	Sept. 23, 1927
Width of taking	150 ft.
Work begun	Oct. 4, 1927
Average area of land cleared per week	3.3 a.
Average area of land grubbed per week	1.0 a.
Average length of channel excavated per week	900 ft.
Maximum length of channel excavated per week	1,125 ft.
Average number of men employed per day	24

Approximately 750 feet of channel remained to be excavated and miscellaneous work to be completed on November 30, 1927. The following is a summary of the work done and materials furnished under the principal items of the contract during the year:

Clearing	25.2 a.
Grubbing	7.0 a.
Excavation	13,500 cu. yds.
Furnishing and placing concrete	31 cu. yds.

Geologic Data

Chapter 321, Acts of 1927, provides that the Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the state. Such information, obtained from sub-surface investigations and construction to date, is as follows:

Surficial Geology. — The line of the Wachusett-Swift Tunnel traverses a portion of the central upland or Worcester County Plateau, recognized as the base level of erosion during the Cretaceous Period. Since the Cretaceous Period, the plateau or peneplain has been dissected by renewed stream action as the result of uplift, and the topography resulting therefrom considerably modified by continental glaciation. The accumulated results of these geologic processes have had a decided effect on the location of the tunnel in direction and in depth. The earth mantle, which obscures the underlying rock formations, is of glacial origin, and occurs as unmodified and modified drift deposits. The unmodified drift is found mostly in the areas covered with the ground moraine, which is confined to the higher elevations, while the modified drift is found entirely in the valleys. The latter deposits were of great importance because of their deposition to unknown depths. Numerous borings, drilled through the modified drift of Glacial Lake Nashua, within the valley of the Quinapoxet River, found bedrock at such a low elevation as to make it necessary to depress the tunnel. The lowest elevation of rock in this area was found at Elevation 373 at the location of Shaft 1, the outlet from the tunnel into the Wachusett Reservoir at the Quinapoxet River basin. This elevation is probably not much higher than the lowest rock in the pre-glacial gorge of the Quinapoxet River. The drift within the valley has been deeply eroded by the present stream, so that the depth of cover determined from numerous borings does not indicate the total depth of glacial deposition in this area. One hole in particular penetrated 114 feet of material and it is quite probable that the original drift in some sections was deposited to a depth of 175 feet or more.

Several borings across the Ware River at Smithville, or White Valley, located the lowest rock in the pre-glacial channel of the Ware River at Elevation 607, which is approximately 40 feet lower than the flow line of the present river. The deepest drift is confined to the south side of the valley, and the deepest hole penetrated 93 feet of material before locating bedrock. Within the same valley, but approximately 3 miles west, at the junction of the Prince River and the Ware River, rock was found as low as Elevation 434, with a corresponding depth of earth cover of 162 feet. A complete profile across the Ware River valley, at this point, was not obtained, and it is quite probable that more holes would have shown rock as low as Elevation 400. Other borings, $\frac{3}{4}$ mile north of this point, but confined to the Prince River valley, indicate that the low rock in the Ware River valley is possibly due to glacial scour and over-deepening of the pre-glacial Ware River valley in this vicinity. The deepest hole on the tunnel line, crossing the Prince River valley, and located in the middle of the valley, penetrated 108 feet of fine-medium sand and boulders before locating rock at Elevation 482. Borings on two tentative lines in the spacious valley now occupied by Muddy Brook indicate that it, too, has its origin in a pre-glacial or inter-glacial river, which obtained its flow from a part of the present Swift River watershed. The reversal of drainage is due to the blocking of the valley by glacial drift, in some places as deep as 135 feet or more. A similar condition exists in Beaver Brook valley, at the dike site, where the lowest rock along the axis was found at Elevation 290, buried to a depth of 142 feet. The Swift River, at the main dam site, flows approximately 130 feet above its pre-glacial channel.

Geologic Formations. — The rocks, along the tunnel line from the Wachusett Reservoir to the dam and dike sites in the Swift River valley, are of several varieties, but in their simplest terms are found to be primarily of the following types:

1. Quartz-mica phyllite, a fine-grained, finely-laminated quartzose rock with variable amounts of mica.
2. Biotite-muscovite granite of medium grain.
3. Quartz-mica schist, a medium-grained, strongly quartzose, more or less distinctly laminated and micaceous rock.
4. Mixed injection schist, an intimate mixture of the quartz-mica schist and phyllite with the granite.
5. Grayish white medium-grained biotite-granite gneiss with differentiation facies to high hornblende-biotite and high quartz rocks.
6. Hornblende-diorite, a differentiation facies of the granite gneiss.

The areal extent of these formations is partly obscured in the field by the glacial drift, and it is quite impossible, at this date, to draw exact boundaries, but their occurrence along the line is in the order named. The structural relations are obscure and uncertain. In the six shafts constructed, the structure was surprisingly flat, and at no shaft has the structure stronger slopes than forty-five degrees. The rock is considerably jointed, some joints of which show rather strong slickensided effects. The rock at Shaft 5, which is a quartz-mica schist, remained of the same character, with the structure horizontal, for the total depth of the shaft. The geologic age of the various formations is problematical, but it is certain that the granite is the younger rock, and that the schists are older metamorphosed sediments.

Due to the difference of opinion as to the geologic age and structural relations of the several rock formations in this area, the intention is to collect and study data obtained from the excavations in the shafts and tunnel. This data, when complete, will give a cross section of the rock formations of Central Massachusetts for a distance of 25 miles or more.

List of Drawings and Tables

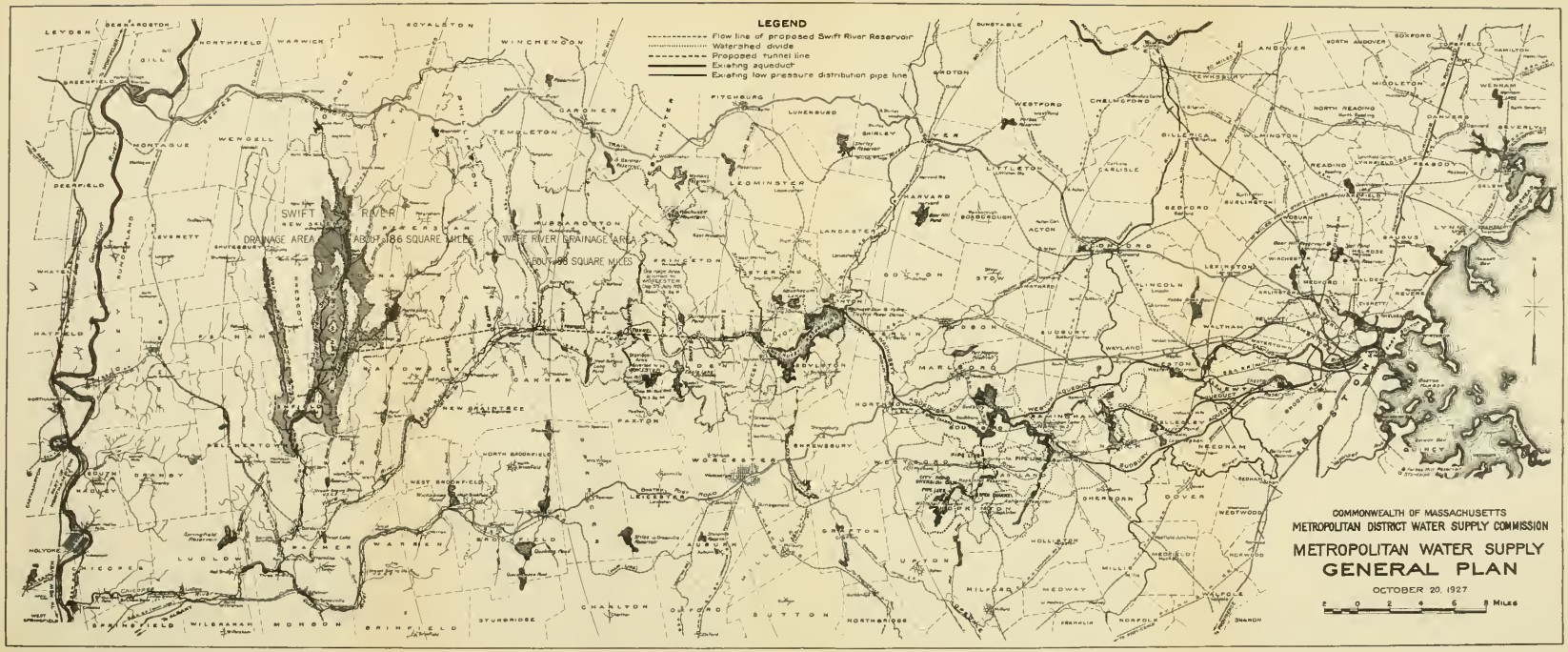
The following drawings and tabulations are appended to this report:

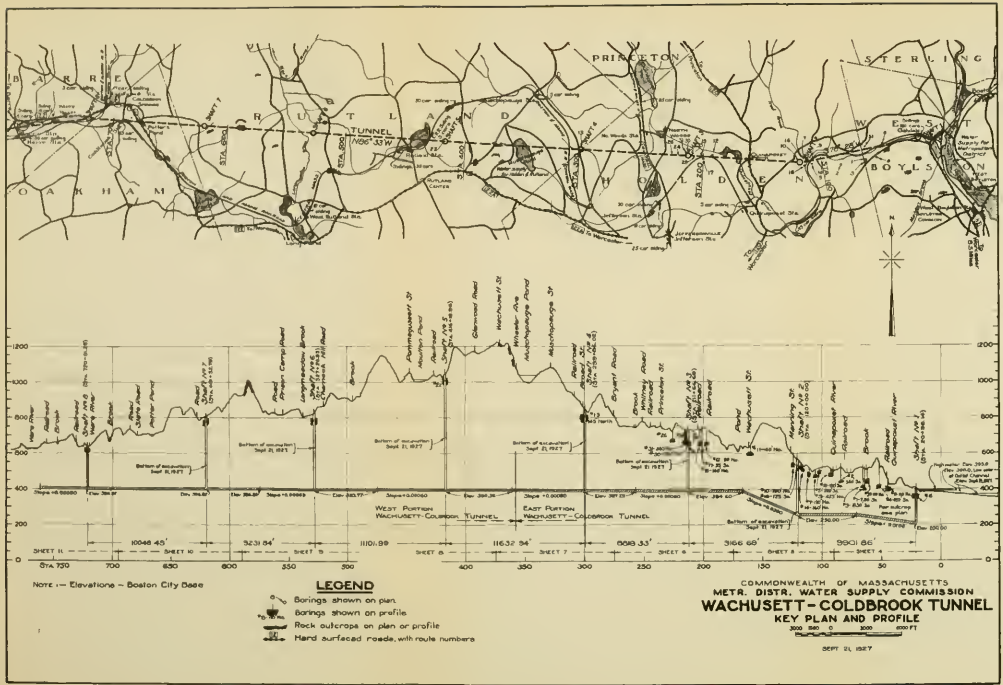
General Plan of Metropolitan Water Supply.
Key Plan and Profile, Wachusett-Coldbrook Tunnel.
Monthly Progress — Real Estate Acquired for the Wachusett-Coldbrook Tunnel.
Location of Real Estate Acquired for the Wachusett-Coldbrook Tunnel.
Monthly Progress — Real Estate Acquired for the Southern Sudbury Emergency Supply.
Location of Real Estate Acquired for the Southern Sudbury Emergency Supply.
Monthly Progress — Real Estate Acquired for the Swift River Reservoir.
Location of Real Estate Acquired for the Swift River Reservoir.
Status of Contracts Executed to November 30, 1927.
Total Value of Work Estimated under Contracts in Progress During Year Ending November 30, 1927.
Canvass of Bids, Contract 4.
Canvass of Bids, Contract 5.
Canvass of Bids, Contract 6.
Canvass of Bids, Contract 7.
Canvass of Bids, Contract 8.
Canvass of Bids, Contract 11.
Canvass of Bids, Contract 12.
Canvass of Bids, Contract 13.
Canvass of Bids, Contract 16.

Respectfully submitted,

FRANK E. WINSOR,
Chief Engineer.

24 School Street, Boston, Mass.
December 1, 1927.


LEGEND
Flow line of proposed Swift River Reservoir
Watershed divide
Proposed tunnel line
Existing aqueduct
Existing low pressure distribution pipe line
SWIFT RIVER DRAINAGE AREA ABOUT 186 SQUARE MILES
WARE RIVER DRAINAGE AREA ABOUT 98 SQUARE MILES
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT WATER SUPPLY COMMISSION
METROPOLITAN WATER SUPPLY
GENERAL PLAN
OCTOBER 20, 1927
2 0 2 4 6 8 Miles



BARRE
RUTLAND
PRINCETON
STERLING
WEST BOYLSTON
HOLDEN
OAKHAM
TUNNEL N86°33'W
STA. 600
STA. 500
STA. 400
STA. 300
STA. 200
STA. 100
WEST PORTION WACHUSETT-COLDBROOK TUNNEL
EAST PORTION WACHUSETT-COLDBROOK TUNNEL
10048.45'
9231.54'
11101.99
11632.54'
8818.33'
9166.68'
9901.86'
SHEET 11
SHEET 10
SHEET 9
SHEET 8
SHEET 7
SHEET 6
SHEET 5
SHEET 4
STA. 730
700
650
600
550
500
400
350
300
250
200
150
100
50
0
NOTE :— Elevations — Boston City Base
LEGEND
Borings shown on plan
Borings shown on profile
Rock outcrops on plan or profile
Hard surfaced roads, with route numbers
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
WACHUSETT-COLDBROOK TUNNEL
KEY PLAN AND PROFILE
3000 1500 0 3000 6000 FT
SEPT 21, 1927

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

MONTHLY PROGRESS — REAL ESTATE ACQUIRED FOR THE WACHUSETT-COLDBROOK TUNNEL.

DATE	TAKING PLANS PREPARED	TAKEN IN FEE (Acres)	EASEMENT FOR TUNNEL (Acres)	EASEMENT FOR POWER LINE (Acres)	EASEMENT FOR TUNNEL AND POWER LINE (Acres)	EASEMENT FOR SURFACE R. of W. (Acres)	FEE & EASEMENT in COMMONWEALTH (Acres)
December 1926							
January 1927							
February							
March							
April	4						
May	6						
June	2						
July		188.34	0.67	1.43	1.05	0.78	192.27
August		96.67	0.98	7.43	0.98	1.53	107.59
September							
October	2						
November		284.83			0.84		285.67
Total	14	569.84	1.65	8.86	2.87	2.31	585.53

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE WACHUSETT COLDBROOK TUNNEL

TOWNS	LENGTH OF TUNNEL (Feet)	TAKEN IN FEE (Acres)	EASEMENT FOR TUNNEL (Acres)	EASEMENT FOR POWER LINE (Acres)	EASEMENT FOR TUNNEL AND POWER LINE (Acres)	EASEMENT SURFACE R. OF W. (Acres)	FEE & EASEMENT IN COMMONWEALTH (Acres)
West Boylston	4,290						
Holden	23,490	186.01	0.67	1.43	1.05	0.76	189.92
Rutland	33,460	92.76	0.45	6.32	0.62	1.53	101.68
Oakham	7,785	110.20	0.53	1.11	0.36		112.20
Barre	* 880	181.25			0.84		182.09
Total	69,905	570.22	1.65	8.86	2.87	2.29	585.89

*Measurements to Shaft 8 only.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

MONTHLY PROGRESS — REAL ESTATE ACQUIRED FOR THE SOUTHERN SUDBURY EMERGENCY SUPPLY

DATE	TAKING PLANS PREPARED	TAKEN IN FEE (Acres)	EASEMENT (Acres)	FEE & EASEMENTS IN COMMONWEALTH (Acres)	
December 1926					
January 1927					
February					
March					
April					
May	5				
June	3				
July	5	1.14	*14.09	15.23	*0.28 acres, easement for period of construction ending Jan. 1, 1928 only
August					
September	1				
October		64.17	4.47	68.64	
November			10.74	10.74	
Total	14	65.31	29.30	94.61	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE SOUTHERN SUDBURY EMERGENCY SUPPLY

TOWNS	TAKEN IN FEE (Acres)	EASEMENT (Acres)	FEE & EASEMENT IN COMMONWEALTH (Acres)	
Southboro	1.14	9.60	10.74	
Ashland		*13.89	*13.89	*0.28 acres, easement for construction only until Jan. 1, 1928.
Hopkinton	64.17	4.47	68.64	
Framingham		1.34	1.34	
Total	65.31	29.30	94.61	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

MONTHLY PROGRESS – REAL ESTATE ACQUIRED FOR THE SWIFT RIVER RESERVOIR

DATE	TOTAL APPLICATIONS LISTED (Acres)	LISTED BUT NOT REQUIRED (Acres)	PLACED UNDER OPTION (Acres)	TITLE VESTED IN COMMONWEALTH (Acres)	
December 1926	1,629	174	586	16	
January 1927	1,704	1	876	1,007	
February	1,597	0	204	728	
March	4,441	57	1,103	493	
April	2,772	90	2,088	563	
May	2,373	217	1,591	513	
June	3,948	151	974	850	
July	1,747	174	1,647	1,337	
August	2,490	347	1,325	1,765	
September	3,847	502	1,675	2,045	
October	2,221	330	1,856	873	
November	825	240	1,444	700	Acreage is based upon estimates obtained from deeds or other information and not from surveys.
Total for Year Ending Nov. 30, 1927	29,594	2,283	15,369	10,890	
Total to Nov. 30, 1926	2,608	185	216		
Total to Nov. 30, 1927	32,202	2,468	15,585	10,890	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE SWIFT RIVER RESERVOIR

TOWNS	TITLE VESTED IN COMMONWEALTH (Acres)	
Belchertown	*230*	
Dana	*920*	
Enfield	*2,385*	
Greenwich	*2418*	
Hardwick	*12*	
New Salem	*380*	
Pelham	*770*	
Petersham	*177*	
Prescott	*3455*	
Ware	*143*	*Acreage is based upon estimates obtained from deeds or other information and not from surveys.*
Total	*10,890*	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS EXECUTED TO NOV. 30, 1927.

CONT. NO.	DESCRIPTION	LOCATION	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	AMOUNT OF CONTRACT	PAYMENTS TO DATE	FINAL ESTIMATE	DATE OF COMPLETION
1.	Borings	Tunnel line	Pennsylvania Drilling Co.	Nov. 5, 1926	Nov. 15, 1926	8,260.00		18,641.69	July 15, 1927
2.	Borings	Swift Dam Sites	Sprague & Henwood, Inc.	Nov. 5, 1926	Nov. 12, 1926	9,730.00		26,885.83	June 3, 1927
3.	Aerial Photographs	Swift Valley	Fairchild Aerial Surveys, Inc.		Nov. 22, 1926	5,600.00 Add. Material 1,355.00	397.50	5,600.00	Oct. 6, 1927
4.	Shaft 5	Rutland	James J. Coughlan & Sons, Inc.	Mar. 25, 1927	Mar. 28, 1927	137,854.80	92,423.16		
5.	Cordaville Pipe Line	Cordaville to Sudbury Res.	Lock Joint Pipe Co.	Apr. 15, 1927	Apr. 15, 1927	78,818.00	74,181.73		
6.	Cordaville Pumping Sta.	Cordaville	F. A. Mazzur Co., Inc.	Apr. 29, 1927	May 2, 1927	16,357.00	14,574.09		
7.	Hopkinton Pipe Line	Hopkinton Res. to Cordaville	Cenedella & Co.	Apr. 29, 1927	May 4, 1927	126,550.00	112,836.10		
8.	Shafts 6 & 7	Rutland	James J. Coughlan & Sons, Inc.	May 20, 1927	May 24, 1927	162,125.00	121,166.73		
9.	Aerial Photographs	Chicopee and Ware Rivers	Fairchild Aerial Surveys, Inc.		Mar. 30, 1927	2,500.00 Add. Material 590.00	22.50	2,500.00	May 7, 1927
10.	Transmission Line for Const. of Wachusett-Coldbrook Tunnel	Tunnel Line	New England Power Co.		Apr. 27, 1927	Construction at cost Maintenance at cost	2,167.01	86,439.58	Sept. 20, 1927
11.	Ashland Pipe Line	Ashland Res. to Reservoir No. 2	Antonio Mogavero	June 3, 1927	June 3, 1927	125,150.00	110,042.86		
12.	Shafts 2, 3 & 4	Holden and Rutland	Dravo Contracting Co.	May 20, 1927	May 24, 1927	259,800.00	181,163.16		
13.	Whitehall Pipe Line	Whitehall Res. to City Road	Portland Contracting Co.	July 15, 1927	July 15, 1927	54,963.00	43,130.46		
15.	Electric Power	Cordaville Pumping Sta.	Marlborough Electric Co.		Aug. 4, 1927				
16.	Whitehall Open Channel	City Road to Hopkinton Res.	Sanders Engineering Co.	Sept. 23, 1927	Sept. 23, 1927	36,720.00	6,239.07		

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

TOTAL VALUE OF WORK ESTIMATED UNDER CONTRACTS IN PROGRESS DURING YEAR ENDING NOV. 30, 1927.

CONTRACT NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16
CONTRACTOR	PENNSYLVANIA DRILL. CO.	SPRAGUE & HENWOOD, INC	FAIRCHILD AERIAL SURVEYS, INC	J.J. COUGHLAN & SONS, INC.	LOCKJOINT PIPE CO.	F.A. MAZZUR & CO. INC.	CENEDELLA & CO.	J.J. COUGHLAN & SONS, INC	FAIRCHILD AERIAL SURVEYS INC.	NEW ENGLAND POWER CO.	ANTONIO MOGAVERO	DRAVO CONT. CO.	PORTLAND CONT. CO.	MARLBOROUGH ELECTRIC CO.	SANDERS ENG. CO.
AMOUNT OF CONTRACT	8,260.00	9,730.00	* 5,600.00 1,355.00	137,854.80	78,818.00	16,357.00	126,550.00	162,125.00	* 2,500.00 590.00		125,150.00	259,800.00	54,963.00		36,720.00
DECEMBER 1926.	317.00														
JANUARY 1927	2,906.20	2,102.01	2,850.00												
FEBRUARY	4,440.40	4,531.39	2,850.00												
MARCH	7,781.55	9,359.50	2,850.00												
APRIL	10,879.85	18,321.29	2,850.00												
MAY	13,699.96	26,885.83	5,050.00	1,023.10					2,500.00						
JUNE	16,747.39	26,885.83	5,050.00	12,061.50	26,185.80	817.85	10,779.80			+40,740.00 293.11					
JULY	18,641.69		5,050.00	31,294.42	52,926.35	4,089.25	25,987.50	4,569.05	22.50	82,788.09 293.11	13,566.34	3,500.00			
AUGUST	SUPPLEMENTARY AGREEMENT.		5,050.00	38,513.03	65,913.20	12,267.75	82,127.25	21,867.78	22.50	82,788.09 293.11	36,652.03	31,432.35	3,882.03		
SEPTEMBER	1,891.45		5,050.00	53,459.32	71,410.80	14,230.59	105,735.06	48,975.05	22.50	86,439.58 847.00	86,165.12	81,302.90	24,660.57		
OCTOBER	4,890.45		5,600.00	78,622.45	77,824.30	15,539.15	118,657.10	96,099.13	22.50	1,409.80	109,118.39	143,863.10	36,862.75		
NOVEMBER 1927.	8,221.80		397.50	102,692.40	82,424.15	16,193.43	125,373.45	134,629.70	22.50	2,407.79	122,269.85	201,292.40	47,922.73		6,932.30

+ Top Figure is Construction Cost.
Lower Figure is Operation and Maintenance Cost.

* Upper Figure is Amount of Contract.
Lower Figure is for Additional Material.

Canvass of Bids for Contract 4 Opened March 25, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract No. 4. Sinking Shaft No. 5 for
Wachusett-Coldbrook Tunnel in
the Town of Rutland.

Canvass of Bids opened Mar. 25, 1927.

Item	Description	Unit	Quantity	+ (1) James J. Coughlan & Sons Inc. 27 School St. Boston, Mass. Price	Amount	(2) Dravo Contracting Co. Dravo Bldg. Pittsburg, Pa. Price	Amount	(3) Bruno & Petitti. 18 Tremont St. Boston Mass. Price	Amount	(4) Mason & Hanger Co. Inc. 32 Vanderbilt Ave. New York City. Price	Amount	(5) Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	(6) Cenedella & Co. 68 School St. Milford, Mass. Price	Amount	(7) Peter F. Connolly Co. 9 Jackson Ave Long Island City, N.Y. Price	Amount	(8) Simpson Bros. Corp. 17 Summer St. Boston, Mass. Price	Amount	(9) Coleman Bros. Inc. 243 State St. Boston, Mass Price	Amount	(10) M. F. Gaddis. 38 Commonwealth Ave. Newton, Mass. Price	Amount	(11) V. J. Grande. 100 Academy Hill Road. Boston, Mass. Price	Amount
1	Earth Excavation.	Cu Yds.	190.	6.50	1,235.00	13.50	2,565.00	10.00	1,800.00	19.50	3,705.00	20.00	3,800.00	30.00	5,700.00	20.00	3,800.00	20.00	3,800.00	10.00	1,800.00	100.00	19,000.00	100.00	19,000.00
2.	Rock Excavation, in Shaft and Tunnel.	" "	5780.	14.90	86,122.00	16.00	92,480.00	20.00	115,600.00	19.50	112,710.00	25.00	144,500.00	30.00	173,400.00	36.00	208,080.00	44.00	254,320.00	50.00	289,000.00	50.00	289,000.00	60.00	346,800.00
3.	Drainage, in Shaft and Tunnel.	Lin Ft	744.	22.20	16,516.80	13.50	10,044.00	2.00	1,488.00	1.00	744.00	2.00	1,488.00	10.00	7,440.00	10.00	7,440.00	21.00	15,624.00	10.00	7,440.00	10.00	7,440.00	20.00	14,880.00
4.	Forms, for Shaft Lining.	" "	632.	15.75	9,954.00	18.00	11,376.00	5.00	3,160.00	5.00	3,160.00	9.00	5,688.00	10.00	6,320.00	10.00	6,320.00	30.00	18,960.00	13.00	8,216.00	20.00	12,640.00	20.00	12,640.00
5.	Concrete Shaft Lining.	Cu Yds.	1540.	11.55	17,787.00	12.00	18,480.00	15.00	23,100.00	17.00	26,180.00	13.00	20,020.00	15.00	23,100.00	17.00	26,180.00	14.00	21,560.00	25.00	38,500.00	10.00	15,400.00	30.00	46,200.00
6.	Portland Cement, for Concrete and Grout.	Bbls.	2400.	2.60	6,240.00	3.00	7,200.00	3.00	7,200.00	3.50	8,400.00	3.00	7,200.00	4.00	9,600.00	4.00	9,600.00	3.50	8,400.00	3.00	7,200.00	5.00	12,000.00	4.00	9,600.00
			Totals		137,854.80		142,145.00		152,448.00		154,899.00		182,696.00		225,560.00		261,420.00		299,544.00		352,256.00		355,480.00		449,120.00

+ Contract awarded on Mar 28, 1927 to James J. Coughlan & Sons Inc.

Canvass of Bids for Contract No. 5, opened Apr. 15, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract 5. Constructing 30 Inch Pipe Line
From Cordaville to Sudbury Reservoir No. 5,
in the Town of Southborough.

Item	Description	Unit	Quantity	① R.C. Lock Joint Pipe Co. P.O. Box, 21. Ampere, N.J. Price	Amount	* ② Cyl. Lock Joint Pipe Co. P.O. Box, 21. Ampere, N.J. Price	Amount	③ R.C. Cenedella & Co. 88 School St. Milford, Mass. Price	Amount	④ C.I. Cenedella & Co. 68 School St. Milford, Mass. Price	Amount	⑤ C.I. J.H. McCusker & Sons. 62 Church St. Waltham, Mass. Price	Amount	⑥ C.I. Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	⑦ C.I. Louis Balboni. 419 Belgrade Ave. West Roxbury, Mass. Price	Amount	⑧ C.I. Vincenzio Barletta. 8 Whipple Ave. Roslindale, Mass. Price	Amount
1	Furnishing 30" ** pipe, and special castings	Lin Ft.	8700	6.00	52,200.00			6.70	58,290.00	7.10	61,770.00	8.27	71,949.00	9.30	80,910.00	8.00	69,600.00	7.40	64,380.00
2.	" 18" C.I. " " " "	" "	220.	4.30	946.00	4.30	946.00	4.35	957.00	4.35	957.00	4.10	902.00	4.50	990.00	4.00	880.00	4.00	880.00
3	" 12" C.I. " " " "	" "	240	2.40	576.00	2.40	576.00	2.50	600.00	2.50	600.00	2.29	549.60	3.00	720.00	2.25	540.00	3.00	720.00
4.	" 24" C.I. or steel pipe and special castings	" "	50.	10.50	525.00	10.50	525.00	8.00	400.00	8.00	400.00	10.25	512.50	12.00	600.00	6.00	300.00	6.00	300.00
5.	Laying 30" pipe and special castings.	" "	8700	.45	3915.00	.45	3915.00	1.60	13,920.00	1.60	13,920.00	.96	8352.00	1.80	15,660.00	1.95	16,965.00	2.25	19,575.00
6.	Laying 18" C.I. pipe and special castings.	" "	220.	.70	154.00	.70	154.00	1.00	220.00	1.00	220.00	6.15	1,353.00	1.60	352.00	2.00	440.00	2.00	440.00
7.	" 12" C.I. " " " "	" "	220.	.60	132.00	.60	132.00	.80	176.00	.80	176.00	6.00	1,320.00	1.60	352.00	2.00	440.00	2.00	440.00
8.	" 24" C.I. " or steel pipe and castings, in Cordaville Mill.	Lump	Sum.		1200.00		1200.00		350.00		350.00		700.00		1,000.00		1,000.00		800.00
9.	Earth excavation, fill and refill.	Cu. Yds.	9000.	1.25	11,250.00	1.25	11,250.00	1.20	10,800.00	1.20	10,800.00	2.00	18,000.00	2.90	26,100.00	1.80	16,200.00	2.25	20,250.00
10.	Furnishing and placing valves, drains, well, gate boxes, etc.	Lump	Sum.		700.00		700.00		750.00		750.00		765.00		2,500.00		1,000.00		400.00
11.	Concrete outlet well.	Lump	Sum.		750.00		750.00		900.00		900.00		800.00		1,000.00		500.00		400.00
12.	Rock excavation and refill.	Cu. Yds.	250.	5.00	1250.00	5.00	1250.00	6.00	1500.00	6.00	1500.00	7.00	1750.00	6.00	1,500.00	10.00	2,500.00	8.00	2000.00
14.	Furnishing 30" reinforced concrete, "Cylinder," Pipe. (Alternate for Item, 1.)	Lin. Ft.	8700			6.60	57,420.00												
	Totals				73,598.00		78,818.00		88,863.00		92,343.00		106,953.10		108,194.00		110,365.00		110,585.00

Item	Description	Unit	Quantity	⑨ C.I. Antonio Mogavero. 6 Dane St. Peabody, Mass. Price	Amount	⑩ C.I. V.N. Famiglietti & Sons, Inc. 166 Broadway, Providence, R.I. Price	Amount	⑪ C.I. Mark E. Kelley, Inc. 35 Foster St. Peabody, Mass. Price	Amount	⑫ C.I. Anthony Baruffaldi, Co. 52 Powderhouse Blvd. Somerville, Mass. Price	Amount	⑬ C.I. Bruno & Petitti. 18 Tremont St. Boston, Mass. Price	Amount	⑭ C.I. Middlesex Construction Co. 24 Union Ave. Framingham, Mass. Price	Amount	⑮ R.C. P.J. Keating, Co. 280 Main St., Fitchburg, Mass. Price	Amount	⑯ C.I. V.J. Grande. 100 Academy Hill Rd. Boston, Mass. Price	Amount
1.	Furnishing 30" ** pipe, and special castings.	Lin. Ft.	8700	8.05	70,035.00	9.50	82,650.00	9.66	84,042.00	8.25	71,775.00	8.25	71,775.00	8.50	73,950.00	8.15	70,905.00	10.00	87,000.00
2.	" 18" C.I. " " " "	" "	220.	3.85	847.00	5.00	1,100.00	4.86	1,069.20	4.50	990.00	5.00	1,100.00	8.50	1,870.00	10.50	2310.00	6.50	1,430.00
3	" 12" C.I. " " " "	" "	240.	2.25	540.00	3.00	720.00	2.00	480.00	3.00	720.00	3.00	720.00	4.50	1,080.00	4.50	1,080.00	4.00	960.00
4	" 24" C.I. or steel pipe and special castings.	" "	50.	10.70	535.00	9.00	450.00	18.76	938.00	10.50	525.00	10.00	500.00	13.50	675.00	20.00	1,000.00	12.50	625.00
5	Laying 30" pipe and special castings.	" "	8700.	1.57	13,659.00	1.50	13,050.00	1.82	15,834.00	1.50	13,050.00	2.00	17,400.00	2.50	21,750.00	1.90	16,530.00	2.50	21,750.00
6	Laying 18" C.I. pipe and special castings.	" "	220.	.75	165.00	.90	198.00	.69	151.80	1.00	220.00	1.00	220.00	1.50	330.00	1.90	418.00	2.50	550.00
7.	" 12" C.I. " " " "	" "	220.	.65	143.00	.60	132.00	.51	112.20	.50	110.00	1.00	220.00	1.50	330.00	1.90	418.00	2.00	440.00
8.	" 24" C.I. " or steel pipe and castings, in Cordaville Mill.	Lump	Sum.		865.00		375.00		877.00		500.00		400.00		2,000.00		1,000.00		500
9.	Earth excavation, fill and refill.	Cu. Yds.	9000.	2.45	22,050.00	1.80	16,200.00	1.60	14,400.00	3.50	31,500.00	3.00	27,000.00	2.50	22,500.00	3.90	35,100.00	2.50	22,500.00
10	Furnishing and placing valves, drains, well, gate boxes, etc.	Lump	Sum.		625.00		500.00		941.00		1,000.00		1,200.00		1,200.00		1,600.00		800.00
11.	Concrete outlet well.	Lump	Sum		650.00		450.00		840.00		500.00		1,000.00		600.00		1,000.00		600.00
12.	Rock excavation and refill.	Cu. Yds.	250.	6.00	1500.00	6.00	1500.00	8.00	2,000.00	5.00	1,250.00	5.00	1,250.00	6.00	1,500.00	7.50	1,875.00	10.00	2500.00
14.	Furnishing 30" reinforced concrete, "Cylinder," Pipe. (Alternate for Item, 1.)	Lin. Ft.	8700.																
	Totals				111,614.00		117,325.00		121,685.20		122,140.00		122,785.00		127,785.00		133,236.00		138,960.00

* Contract awarded on Apr 15, 1927, to the Lock Joint Pipe Co.

** Note:- C.I. = Cast Iron Pipe. R.C. = Reinforced Concrete Pipe. Cyl. = Reinforced Concrete Cylinder Pipe.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

CONTRACT 6.

CONSTRUCTING A PUMPING STATION IN THE TOWN OF SOUTHBOROUGH.

CANVASS OF BIDS FOR CONTRACT 6, OPENED APRIL 29, 1927.

No.	NAME & ADDRESS OF BIDDER	AMOUNT.	REMARKS.
1	* F.A. Mazzur Co., Inc. 141 Milk St. Boston, Mass.	16,297 - 16,997.	Depending on the make of equipment to be furnished.
2	Hydraulic Development Co. 296 Boylston St. Boston, Mass.	16,379 - 16,824.	do
3	Joel E. Ballentine Co. 79 Sudbury St. Boston, Mass.	17,000.	
4	Starkweather & Broadhurst, Inc. 79 Milk St. Boston, Mass.	17,430.	
5	Guiney & Hanson Const. Co. 172 Milk St. Boston, Mass.	18,000	
6	M. J. Ahearn, Inc. 129 Washington St. Boston, Mass.	18,670 - 18,845.	Depending on the make of equipment to be furnished.
7	Rideout, Chandler & Joyce Inc. 172 High St. Boston, Mass.	19,320. - 20,350.	do.
8	Mark E. Kelly Co., Inc. 35 Foster St. Peabody, Mass.	19,893.	
9	V. J. Grande 100 Academy Hill Road Brighton, Mass.	28,000.	
10	Anthony Baruffaldi 52 Powder House Blvd. Somerville, Mass.	34,500.	

* Contract Awarded May 2, 1927 to F.A. Mazzur Co., Inc. for $16,357.00

Canvass of Bids for Contract No. 7, Opened April 29, 1927.

Commonwealth of Massachusetts Metr. Distr. Water Supply Commission. Contract 7. Constructing 30 Inch Pipe Line From Hopkinton Reservoir to Cordaville in the Towns of Ashland and Southborough.				* ① R.C. Cenedella & Co. 68 School St. Milford, Mass.		② C.I. Mark E. Kelly Co. Inc. 35 Foster St. Peabody, Mass.		③ R.C. Lock Joint Pipe Co. P.O. Box. 21. Ampere, N.J.		④ Cyl. Lock Joint Pipe Co. P.O. Box. 21. Ampere, N.J.		⑤ C.I. Connecticut Concrete, Co. 65 Jefferson St. Waterbury, Conn.		⑥ C.I. Anthony Baruffaldi. 32 Powderhouse Blvd. Somerville, Mass.	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1.	Connection to 48" outlet pipe.	Lump	Sum		3,500.00		3,702.00		5,000.00		5,000.00		1,000.00		5,000.00
2.	Furnishing 30" diam. pipe, and special castings.‡	Lin. Ft.	7000	6.00	42,000.00	9.69	67,830.00	6.60	46,200.00			12.00	84,000.00	8.00	56,000.00
3.	Laying 30" pipe and special castings.	" "	7000	3.00	21,000.00	1.82	12,740.00	2.50	17,500.00	2.50	17,500.00	2.90	20,300.00	5.00	35,000.00
4.	Excavation, fill and refill, from, 48" connection to Sta. 43+00.	Cu. Yds.	3500	4.90	17,150.00	4.15	14,525.00	10.00	35,000.00	10.00	35,000.00	3.00	10,500.00	5.00	17,500.00
5.	" " " " " 43+00 to connection at Cordaville.	" "	7000	2.85	19,950.00	3.35	23,450.00	4.00	28,000.00	4.00	28,000.00	3.00	21,000.00	5.00	35,000.00
6.	Sudbury River Crossing.	Lump	Sum		6,000.00		4,640.00		3,500.00		3,500.00		2,000.00		5,000.00
7.	Connection to 30" pipe line at Cordaville.	Lump	Sum		3,500.00		3,285.00		3,200.00		3,200.00		500.00		3,000.00
8.	Furnishing and placing paving.	Cu. Yds.	100	8.00	800.00	8.50	850.00	5.00	500.00	5.00	500.00	4.00	400.00	10.00	1,000.00
9.	" " " riprap.	" "	300	4.00	1,200.00	4.00	1,200.00	3.00	900.00	3.00	900.00	4.00	1,200.00	15.00	4,500.00
10.	" " " concrete.	" "	20	30.00	600.00	20.00	400.00	40.00	800.00	40.00	800.00	25.00	500.00	15.00	300.00
11.	Furnishing and placing 18" C.I. Culvert pipe.	Lin. Ft.	100	6.00	600.00	6.05	605.00	4.50	450.00	4.50	450.00	10.00	1,000.00	10.00	1,000.00
12.	" " constructing 6" blowoffs.		2	125.00	250.00	305.00	610.00	75.00	150.00	75.00	150.00	400.00	800.00	75.00	150.00
13.	" " " 4" " .		1	100.00	100.00	285.00	285.00	60.00	60.00	60.00	60.00	300.00	300.00	50.00	50.00
14.	" " " 2" air reliefs.		2	225.00	450.00	990.00	1,980.00	400.00	800.00	400.00	800.00	100.00	200.00	100.00	200.00
16.	" 30" Cylinder pipe & special castings. (Alternate for Item 2.)	Lin. Ft.	7000							6.60	46,200.00				
			Totals.		117,100.00		136,102.00		142,060.00		142,060.00		143,700.00		163,700.00

‡ Note:- C.I. = Cast Iron Pipe. R.C. = Reinforced Concrete Pipe. Cyl. = Reinforced Concrete Cylinder Pipe.

* Contract awarded on May 4, 1927, to Cenedella & Co., on basis of cast iron pipe at $7.35 per lin. ft. instead of reinforced concrete pipe for Item #2. Total $126,550.00

Canvass of Bids for Contract 8 Opened May 20, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract 8
Sinking Shaft No. 6 for Wachusett Coldbrook Tunnel in Town of Rutland

Item	Description	Unit	Quantity	James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass. Price	Amount	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Price	Amount	A. Phelps & Sons 5150 Braden St. Detroit, Mich. Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	Anthony Baroffaldi 52 Powder House Blvd. Somerville, Mass. Price	Amount	Bruno & Petitti 18 Tremont St. Boston, Mass. Price	Amount	V. J. Grande 100 Academy Hill Rd. Boston, Mass, Price	Amount
				Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A	
1-6	Earth excavation to surface of rock.	Cu. Yds.	250	6.50	1,625.00	10.00	2,500.00	30.00	7,500.00	20.00	5,000.00	10.00	2,500.00	20.00	5,000.00	50.00	12,500.00
2-6	Rock excavation in shaft and tunnel.	Cu. Yds.	3,900	13.65	53,235.00	13.50	52,650.00	20.00	78,000.00	20.00	78,000.00	20.00	78,000.00	25.00	97,500.00	32.00	124,800.00
3-6	Shaft and tunnel drainage.	Lin. Ft.	510	9.75	4,972.50	15.00	7,650.00	2.00	1,020.00	10.00	5,100.00	15.00	7,650.00	10.00	5,100.00	15.00	7,650.00
4-6	Forms for concrete lining.	Lin. Ft.	400	15.75	6,300.00	21.50	8,600.00	13.00	5,200.00	10.00	4,000.00	10.00	4,000.00	10.00	4,000.00	15.00	6,000.00
5-6	Concrete lining.	Cu. Yds.	1,000	11.55	11,550.00	17.00	17,000.00	7.00	7,000.00	12.50	12,500.00	15.00	15,000.00	30.00	30,000.00	15.00	15,000.00
6-6	Portland cement.	Bbls.	1,600	2.70	4,320.00	3.20	5,120.00	4.00	6,400.00	3.00	4,800.00	3.00	4,800.00	4.00	6,400.00	3.50	5,600.00
					82,002.50		93,520.00		105,120.00		109,400.00		111,950.00		148,000.00		174,550.00

Item	Description	Unit	Quantity	James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass. Price	Amount	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass. Price	Amount	Dravo Cont. Co. Dravo. Bldg. Pittsburg, Pa. Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	M. F. Gaddis 6 Deacon St. Boston, Mass. Price	Amount
				* Alternate B		Alternate B		Alternate B		Alternate C		Alternate C		Alternate C		Alternate C	
1-6	Earth excavation to surface of rock.	Cu. Yds.	250	6.50	1,625.00	10.00	2,500.00	21.00	5,250.00	6.50	1,625.00	10.00	2,500.00	19.00	4,750.00	20.00	5,000.00
2-6	Rock excavation in shaft and tunnel.	Cu. Yds.	3,900	13.65	53,235.00	13.00	50,700.00	21.00	81,900.00	13.65	53,235.00	12.50	48,750.00	19.00	74,100.00	21.00	81,900.00
3-6	Shaft and tunnel drainage.	Lin. Ft.	510	9.75	4,972.50	15.00	7,650.00	10.00	5,100.00	9.75	4,972.50	15.00	7,650.00	10.00	5,100.00	5.00	2,550.00
4-6	Forms for concrete lining.	Lin. Ft.	400	15.75	6,300.00	21.50	8,600.00	10.00	4,000.00	15.75	6,300.00	21.50	8,600.00	10.00	4,000.00	3.00	1,200.00
5-6	Concrete lining.	Cu. Yds.	1,000	11.55	11,550.00	17.00	17,000.00	12.50	12,500.00	11.55	11,550.00	17.00	17,000.00	12.50	12,500.00	10.50	10,500.00
6-6	Portland cement	Bbls.	1,600	2.70	4,320.00	3.20	5,120.00	3.00	4,800.00	2.70	4,320.00	3.20	5,120.00	3.00	4,800.00	4.00	6,400.00
					82,002.50		91,570.00		113,550.00		82,002.50		89,620.00		105,250.00		107,550.00

* Contract awarded to James J. Coughlan & Sons Inc. May 26, 1927.

Canvass of Bids for Contract 8 Opened May 20, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract 8
Sinking Shaft No. 7 for Wachusett Coldbrook Tunnel in Town of Rutland

Item	Description	Unit	Quantity	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Price	Amount	A. Phelps & Sons 5130 Braden St. Detroit, Mich. Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	Anthony Barsuffaldi 52 Powder House Blvd. Somerville, Mass. Price	Amount	Bruno & Petitti 18 Tremont St. Boston, Mass. Price	Amount	V. J. Grande 100 Academey Hill Rd. Boston, Mass. Price	Amount	Price	Amount
				Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A	
1-7	Earth excavation to surface of rock.	Cu. Yds.	175	10.00	1,750.00	30.00	5,250.00	20.00	3,500.00	10.00	1,750.00	30.00	5,250.00	50.00	8,750.00		
2-7	Rock excavation in shaft and Tunnel.	Cu. Yds.	3800	13.50	51,300.00	20.00	76,000.00	20.00	76,000.00	20.00	76,000.00	30.00	114,000.00	34.00	129,200.00		
3-7	Shaft and Tunnel drainage.	Lin. Ft.	490	15.00	7,350.00	2.00	980.00	10.00	4,900.00	15.00	7,350.00	10.00	4,900.00	15.00	7,350.00		
4-7	Forms for concrete lining.	Lin. Ft.	380	21.50	8,170.00	13.00	4,940.00	10.00	3,800.00	10.00	3,800.00	10.00	3,800.00	15.00	5,700.00		
5-7	Concrete lining.	Cu. Yds.	950	17.00	16,150.00	7.00	6,650.00	12.50	11,875.00	15.00	14,250.00	30.00	28,500.00	15.00	14,250.00		
6-7	Portland cement.	Bbls.	1,500	3.20	4,800.00	4.00	6,000.00	3.00	4,500.00	3.00	4,500.00	4.00	6,000.00	3.50	5,250.00		
					89,520.00		99,820.00		104,575.00		107,650.00		162,450.00		170,500.00		

Item	Description	Unit	Quantity	James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass. Price	Amount	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston N.Y. Price	Amount	James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass. Price	Amount	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Price	Amount	M. F. Gaddis 6 Beacon St. Boston Mass. Price	Amount
				Alternate B		Alternate B		Alternate B		Alternate C		Alternate C		Alternate C		Alternate C	
1-7	Earth excavation to surface of rock.	Cu. Yds.	175	6.50	1,137.50	10.00	1,750.00	21.00	3,675.00	6.50	1,137.50	10.00	1,750.00	19.00	3,325.00	20.00	3,500.00
2-7	Rock excavation in shaft and Tunnel.	Cu. Yds.	3800	14.00	53,200.00	13.00	49,400.00	21.00	79,800.00	14.00	53,200.00	12.50	47,500.00	19.00	72,200.00	21.00	79,800.00
3-7	Shaft and Tunnel drainage	Lin. Ft.	490	9.75	4,777.50	15.00	7,350.00	10.00	4,900.00	9.75	4,777.50	15.00	7,350.00	10.00	4,900.00	5.00	2,450.00
4-7	Forms for concrete lining	Lin. Ft.	380	15.75	5,985.00	21.50	8,170.00	10.00	3,800.00	15.75	5,985.00	21.50	8,170.00	10.00	3,800.00	3.00	1,140.00
5-7	Concrete lining.	Cu. Yds.	950	11.55	10,972.50	17.00	16,150.00	12.50	11,875.00	11.55	10,972.50	17.00	16,150.00	12.50	11,875.00	10.50	9,975.00
6-7	Portland cement.	Bbls.	1,500	2.70	4,050.00	3.20	4,800.00	3.00	4,500.00	2.70	4,050.00	3.20	4,800.00	3.00	4,500.00	4.00	6,000.00
					80,122.50		87,620.00		109,550.00		80,122.50		85,720.00		100,600.00		102,865.00

* Contract awarded to James J. Coughlan & Sons Inc. May 24, 1927.

*Canvass of Bids for Contracts 8 and 12†

Contractors Bidding On	Shaft 2	Shaft 3	Shaft 4	Shaft 6	Shaft 7
*James J. Coughlan & Sons, Inc. Boston, Mass.	72,958.80 (5)	89,051.90 (5)	90,005.00 (1)	82,002.50 (1)	80,122.50 (2) of 2, 6, & 7 only
**Dravo Contracting Co. Pittsburg, Pa.	70,310.00 (5)	86,250.00 (5)	98,190.00 (5)	89,620.00 (5)	85,720.00 (5)
" " " " "	71,810.00 (3)	87,700.00 (3)	100,290.00 (3)	91,570.00 (3)	87,620.00 (3)
" " " " "	73,310.00 (1)	89,150.00 (1)	102,390.00 (1)	93,520.00 (1)	89,520.00 (1)
A. Phelps & Sons, Detroit, Mich.	82,610.00 (1)	125,115.00 (1)	107,590.00 (1)	105,120.00 (1)	99,820.00 (1)
Winston & Co., Inc., Kingston, N.Y.	81,825.00 (3)	94,800.00 (3)	115,625.00 (3)	113,550.00 (3)	109,550.00 (3)
" " " " "	81,825.00 (5)	94,800.00 (5)	115,625.00 (5)	105,250.00 (5)	100,600.00 (5)
" " " " "	85,100.00 (1)	101,950.00 (1)	120,050.00 (1)	109,400.00 (1)	104,575.00 (1)
M.F. Gaddis, Boston, Mass.	85,400.00 (5)	97,765.00 (5)	119,320.00 (5)	107,550.00 (5)	103,865.00 (5)
Anthony Baruffaldi, Somerville, Mass	105,250.00 (1)	146,100.00 (1)	121,650.00 (1)	111,950.00 (1)	107,650.00 (1)
Bruno & Petitti, Boston, Mass.	111,000.00 (1)	151,750.00 (1)	161,500.00 (1)	148,000.00 (1)	162,450.00 (1)
V. J. Grande, Boston, Mass.	174,430.00 (1)	275,350.00 (1)	252,100.00 (1)	171,550.00 (1)	170,500.00 (1)
G.R. Lavallee, Worcester, Mass.	Informal bid only.				

The number in the circle opposite each price bid indicates the least total number of shafts which must be included in the contract and means that this price applies to this shaft, only in case a contract is awarded to this bidder for at least this total number of shafts and at the prices for the other shafts shown in the same horizontal line.

*Advertised as Contract 8

Eleven Low Bid Combinations

Coughlan, Shafts, 4-6-7. Dravo-Shafts 2-3	= 414,670.00
" " 2-3-4-6-7	= 415,020.70
" " 4-6 Dravo, Shafts 2-3-7	= 419,217.50
" " 4-7 " " 2-3-6	= 421,287.50
* " " 6-7 ** " " 2-3-4	= 421,925.00
" " 4-6-7 " " 3. Phelps Shaft 2	= 423,970.00
" " 4-6-7 " " 3. Winston " 2	= 426,460.00
" " 4-6-7 " " 2 " " 3	= 427,470.00
" " 4 " " 2-3-6-7	= 428,785.00
" " 6 " " 2-3-4-7	= 429,422.50
Dravo " 2-3-4-6-7	= 430,090.00

*Contract 8 awarded to Coughlan for Shafts 6 & 7 for $162,125.00 May
** " 12 " " Dravo " " 2, 3 & 4 $259,800.00 24, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contracts 8 & 12†
Sinking Shafts No. 2, 3, 4, 6, & 7 for Wachusett-Coldbrook Tunnel in Towns of Rutland and Holden

Canvass of Bids for Contract 11 Opened June 3, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract No. 11 Constructing 24" Pipe Line From Ashland Reservoir to Gate House at Framingham Reservoir No. 2 in the Towns of Ashland and Framingham.

Item	Description	Unit	Quantity	* (1) Antonio Mogavero, 6 Dane St., Peabody, Mass.		(2) Lock Joint Pipe Co., Ampere, N.J.		(3) Mark E. Kelley Co. Inc., 33 Foster St., Peabody, Mass.		(4) C. Nedellas & Co., 68 School St., Milford, Mass.		(5) General Contracting Co. Inc., 32 Beach Ave., Salem, Mass.		(6) Anthony Baruffaldi, 37 Powder House Blvd., Somerville, Mass.		(7) Taylor Construction Co., 42 Main St., Milford, Mass.		(8) John H. McCusker, 62 Church St., Waltham, Mass.		(9) Vincenzo Barletta, 8 Whipple Ave., Roslindale, Mass.		(10) Winston & Co. Inc., 240 Fair St., Kingston, N.Y.		(11) Louis Balboni, 419 Belgrade Ave., West Roxbury, Mass.		(12) V. J. Grande, 100 Academy Hill Rd., Boston, Mass.	
				Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1	Connection to 48" outlet pipe at Ashland Reservoir.	Lump	Sum		1800.00		1800.00		2170.00		2300.00		1450.00		1500.00		400.00		2906.00		3900.00		2000.00		1800.00		4500.00
2	Furnishing 24" Cast Iron Pipe, or	Lin. Ft.	12,500	5.30	71,550.00			6.23	84,105.00	5.70	76,950.00	4.93	66,555.00	5.00	67,500.00	6.00	81,000.00	7.02	94,770.00	5.00	67,500.00	6.50	87,750.00	6.00	81,000.00	5.75	77,625.00
	Furnishing 24" reinforced concrete "cylinder" pipe.	Lin. Ft.	12,500			6.00	81,000.00																				
3	Furnishing 20" cast iron pipe and special castings.	Lin. Ft.	1000	4.30	4300.00	5.50	5500.00	5.26	5260.00	5.00	5000.00	3.70	3700.00	4.00	4000.00	5.00	5000.00	5.60	5600.00	3.81	3810.00	6.00	6000.00	5.50	5500.00	5.00	5000.00
4	Laying 24" pipe and special castings.	Lin. Ft.	13,500	0.65	8775.00	0.50	6750.00	0.79	10,665.00	1.15	15,525.00	1.50	20,250.00	2.00	27,000.00	0.80	10,800.00	0.59	7965.00	2.15	29,025.00	1.50	20,250.00	2.50	33,750.00	4.00	54,000.00
5	Laying 20" cast iron pipe and special castings.	Lin. Ft.	1000	0.65	650.00	1.30	1300.00	0.65	650.00	1.55	1550.00	1.40	1,400.00	2.00	2000.00	0.70	700.00	0.54	540.00	3.00	3000.00	2.00	2000.00	10.00	10,000.00	5.00	5000.00
6	Earth excavation, fill and refill.	Cu. Yds.	12,500	1.49	18,625.00	1.40	17,500.00	1.60	20,000.00	1.46	18,250.00	2.40	30,000.00	2.00	25,000.00	2.50	31,250.00	1.25	15,625.00	2.20	27,500.00	2.00	25,000.00	2.00	25,000.00	2.00	25,000.00
7	Rock excavation and refill.	Cu. Yds.	100	5.00	500.00	4.00	400.00	7.00	700.00	8.00	800.00	12.00	1200.00	5.00	500.00	10.00	1,000.00	7.00	700.00	7.00	700.00	5.00	700.00	8.00	800.00	8.00	800.00
8	Upper crossing of Framingham Reservoir No. 2.	Lump	Sum		900.00		4000.00		4750.00		2000.00		4800.00		2000.00		4,000.00		4570.00		4500.00		4,000.00		4000.00		2500.00
9	Crossing of Boston & Albany Railroad.	Lump	Sum		2500.00		6,000.00		769.00		3300.00		3000.00		3200.00		4,000.00		4,000.00		3,000.00		2200.00		5,000.00		3500.00
10	Connection to Gate House and lower crossing of Reservoir.	Lump	Sum		11,000.00		7000.00		6,349.00		8,000.00		5,500.00		5000.00		5,000.00		6,850.00		8,000.00		10,000.00		5,000.00		6,000.00
11	Furnishing and placing paving.	Cu. Yds.	10	10.00	100.00	10.00	100.00	8.00	80.00	10.00	100.00	15.00	150.00	10.00	100.00	8.00	80.00	20.00	200.00	10.00	100.00	10.00	100.00	10.00	100.00	10.00	100.00
12	Furnishing and placing riprap	Cu. Yds.	75	8.00	600.00	4.00	300.00	4.00	300.00	4.00	300.00	12.00	900.00	4.00	300.00	4.50	337.50	12.00	900.00	10.00	750.00	5.00	375.00	10.00	750.00	7.00	525.00
13	Furnishing and placing concrete.	Cu. Yds.	50	20.00	1,000.00	30.00	1500.00	20.00	1,000.00	20.00	1,000.00	25.00	1250.00	10.00	500.00	30.00	1500.00	25.00	1250.00	25.00	1250.00	30.00	1500.00	30.00	1500.00	12.00	600.00
14	Furnishing and placing 18" cast iron culvert pipe.	Lin. Ft.	120	7.50	900.00	5.50	660.00	6.05	726.00	5.00	600.00	7.00	840.00	7.00	840.00	6.00	720.00	4.50	540.00	7.00	840.00	5.00	600.00	10.00	1200.00	5.00	600.00
15	Furnishing and constructing 6" blow-offs.		3	150.00	450.00	200.00	600.00	200.00	600.00	125.00	375.00	150.00	450.00	75.00	225.00	25.00	75.00	168.00	504.00	150.00	450.00	100.00	300.00	50.00	150.00	100.00	300.00
16	Furnishing and constructing 4" blow-offs.		2	150.00	300.00	100.00	200.00	175.00	350.00	100.00	200.00	125.00	250.00	75.00	150.00	25.00	50.00	53.00	106.00	125.00	250.00	100.00	200.00	50.00	100.00	50.00	100.00
17	Furnishing and constructing 2" air-relief.		1	100.00	100.00	100.00	100.00	150.00	150.00	200.00	200.00	75.00	75.00	150.00	150.00	50.00	50.00	40.50	40.50	75.00	75.00	50.00	50.00	50.00	50.00	25.00	25.00
18	Installing 20"x10" Venturi meter and appurtenances.	Lump	Sum	100.00	100.00		300.00		460.00		600.00		350.00		300.00		200.00		260.00		300.00		200.00		1000.00		1800.00
					135,150.00		132,010.00		136,033.00		137,550.00		138,320.00		140,265.00		143,162.50		143,176.50		151,250.00		177,335.00		170,900.00		186,075.00

* Contract awarded to Antonio Mogavero, June 3, 1927

CANVASS OF BIDS FOR CONTRACT 12† OPENED MAY 20, 1927.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
CONTRACT 12†
SINKING SHAFT NO. 2 FOR WACHUSETT COLDBROOK TUNNEL IN TOWN OF HOLDEN

				Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa.		A. Phelps & Sons 5150 Braden St. Detroit, Mich.		Winston & Co. Inc. 240 Fair St. Kingston, N.Y.		Anthony Barufealdi 52 Powder Ho. Blvd. Somerville, Mass.		Bruno & Petitti 18 Tremont St. Boston, Mass.		*G.R. Lavallee 20 Clement St. Worcester, Mass.		V. J. Grande 100 Academy Hill Rd. Boston, Mass.	
				Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1-2	Earth excavation to surface of rock	Cu. Yds.	275	10.00	2750.00	30.00	8250.00	20.00	5500.00	10.00	2750.00	20.00	5500.00	3.00	825.00	60.00	16,500.00
2-2	Rock excavation in shaft and tunnel	Cu. Yds.	3000	14.00	42000.00	20.00	60,000.00	20.00	60,000.00	27.00	81,000.00	25.00	75,000.00	30.00	90,000.00	42.00	126,000.00
3-2	Shaft and tunnel drainage	Lin. Ft.	400	15.00	6000.00	2.00	800.00	10.00	4000.00	15.00	6,000.00	10.00	4000.00	4.50	1800.00	25.00	10,000.00
4-2	Forms for concrete lining	Lin. Ft.	240	22.00	5280.00	14.00	3360.00	10.00	2400.00	10.00	2400.00	10.00	2400.00	50.00	12000.00	22.00	5,280.00
5-2	Concrete lining	Cu. Yds.	600	16.00	9600.00	7.00	4,200.00	12.50	7500.00	15.00	9000.00	30.00	18,000.00	17.50	10,500.00	15.00	9,000.00
6-2	Portland cement	Bbls.	900	3.20	2880.00	4.00	3600.00	3.00	2700.00	3.00	2700.00	4.00	3600.00	3.00	2700.00	3.50	3,150.00
7-2	Liquid chlorine	Lbs.	2000	15¢	300.00	20¢	400.00	25¢	500.00	20¢	400.00	25¢	500.00	15%	above cost	1.50	3,000.00
8-2	Chlorine dosing machine		1	4500	4500.00	2200	2000.00	2500	2500.00	1000	1000.00	2000	2000.00	20%	" "	6500	6500.00
					73,310.00		82,610.00		85,100.00		105,250.00		111,000.00	Items 2-5 Only Subtotal	117,825.00		174,430.00

				*Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa.		Winston & Co. Inc. 240 Fair St. Kingston, N.Y.		Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa.		James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass.		Winston & Co. Inc. 240 Fair St. Kingston, N.Y.		M.F. Gaddis 6 Beacon St. Boston, Mass.	
				Alternate B		Alternate B		Alternate C		Alternate C		Alternate C		Alternate C	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1-2	Earth excavation to surface of rock	Cu. Yds.	275	10.00	2750.00	19.00	5225.00	10.00	2750.00	10.00	2750.00	19.00	5225.00	20.00	5500.00
2-2	Rock excavation in shaft and tunnel	Cu. Yds.	3000	13.50	40,500.00	19.00	57,000.00	13.00	39000.00	14.90	44,700.00	19.00	57,000.00	21.00	63000.00
3-2	Shaft and tunnel drainage	Lin. Ft.	400	15.00	6000.00	10.00	4,000.00	15.00	6000.00	22.20	8880.00	10.00	4000.00	5.00	2000.00
4-2	Forms for concrete lining	Lin. Ft.	240	22.00	5280.00	10.00	2,400.00	22.00	5280.00	18.62	4468.80	10.00	2400.00	3.00	720.00
5-2	Concrete lining	Cu. Yds.	600	16.00	9600.00	12.50	7500.00	16.00	9600.00	11.55	6930.00	12.50	7500.00	10.50	6300.00
6-2	Portland cement	Bbls.	900	3.20	2880.00	3.00	2700.00	3.20	2880.00	2.70	2430.00	3.00	2700.00	4.00	3600.00
7-2	Liquid chlorine	Lbs.	2000	15¢	300.00	25¢	500.00	15¢	300.00	15¢	300.00	25¢	500.00	14¢	280.00
8-2	Chlorine dosing machine		1	4500	4500.00	2500	2500.00	4500	4500.00	2500	2500.00	2500	2500.00	4000	4000.00
					71,810.00		81,825.00		70,310.00		72,958.80		81,825.00		83,400.00

†Advertised as Contract 8

*Informal bid.

*Contract awarded to Dravo Cont. Co. May 24, 1927.

Canvass of Bids for Contract 12† Opened May 20, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract 12†
Sinking Shaft No. 3 for Wachusett Coldbrook Tunnel in Town of Holden

Item	Description	Unit	Quantity	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Alternate A Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Alternate A Price	Amount	A. Phelps & Sons 3150 Braden St. Detroit, Mich. Alternate A Price	Amount	Anthony Baruffaldi 52 Powder Ho Blvd. Somerville, Mass. Alternate A Price	Amount	Bruno & Petitti 18 Tremont St. Boston, Mass. Alternate A Price	Amount	V. J. Grande 100 Academey Hill Rd. Boston, Mass. Alternate A Price	Amount
1-3	Earth excavation to surface of rock.	Cu. Yds.	675	10.00	6,750.00	21.00	14,175.00	45.00	30,375.00	30.00	20,250.00	30.00	20,250.00	100.00	67,500.00
2-3	Rock excavation in shaft and tunnel.	Cu. Yds.	2900	14.00	40,600.00	21.00	60,900.00	24.00	69,600.00	30.00	87,000.00	30.00	87,000.00	52.00	150,800.00
3-3	Shaft and tunnel drainage.	Lin. Ft.	430	15.00	6,450.00	10.00	4,300.00	2.00	860.00	25.00	10,750.00	10.00	4,300.00	25.00	10,750.00
4-3	Forms for concrete lining.	Lin. Ft.	320	30.00	9,600.00	10.00	3,200.00	14.00	4,480.00	10.00	3,200.00	10.00	3,200.00	40.00	12,800.00
5-3	Concrete lining.	Cu. Yds.	950	17.00	16,150.00	12.50	11,875.00	12.00	11,400.00	20.00	19,000.00	30.00	28,500.00	25.00	23,750.00
6-3	Portland cement.	Bbls.	1,500	3.20	4800.00	3.00	4500.00	4.00	6000.00	3.00	4500.00	4.00	6,000.00	3.50	5,250.00
7-3	Liquid chlorine.	Lbs.	2000	15¢	300.00	25¢	500.00	20¢	400.00	20¢	400.00	25¢	500.00	1.50	3000.00
8-3	Chlorine dosing machine.		1	4500	4500.00	2500	2500.00	2000	2000.00	1000	1000.00	2000	2000.00	4500	4500.00
					89,150.00		101,950.00		125,115.00		146,100.00		151,750.00		275,350.00

Item	Description	Unit	Quantity	Dravo Cont. Co.* Dravo Bldg. Pittsburg, Pa. Alternate B Price	Amount	Winston & Co. Inc. 240 Fair St. Kingston, N.Y. Alternate B Price	Amount	Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa. Alternate C Price	Amount	James I. Coughlan & Sons, Inc. 27 School St. Boston, Mass. Alternate C Price	Amount	Winston & Co. Inc. 240 Fair St. Boston, Mass. Alternate C Price	Amount	M. F. Gaddis 6 Beacon St. Boston, Mass. Alternate C Price	Amount
1-3	Earth excavation to surface of rock	Cu. Yds.	675	10.00	6750.00	19.00	12,825.00	10.00	6750.00	15.00	10,125.00	19.00	12,875.00	20.00	13,500.00
2-3	Rock excavation in shaft and tunnel	Cu. Yds.	2900	13.50	39,150.00	19.00	55,100.00	13.00	37,700.00	16.00	46,400.00	19.00	55,100.00	21.00	60,900.00
3-3	Shaft and tunnel drainage	Lin. Ft.	430	15.00	6450.00	10.00	4300.00	15.00	6450.00	22.20	9546.00	10.00	4300.00	5.00	2150.00
4-3	Forms for concrete lining	Lin. Ft.	320	30.00	9600.00	10.00	3200.00	30.00	9600.00	18.62	5958.40	10.00	3200.00	3.00	960.00
5-3	Concrete lining	Cu. Yds.	950	17.00	16,150.00	12.50	11875.00	17.00	16,150.00	11.55	10,972.50	12.50	11875.00	10.50	9975.00
6-3	Portland cement	Bbls.	1500	3.20	4800.00	3.00	4500.00	3.20	4800.00	2.70	4050.00	3.00	4500.00	4.00	6,000.00
7-3	Liquid chlorine	Lbs.	2000	15¢	300.00	25¢	500.00	15¢	300.00	15¢	300.00	25¢	500.00	14¢	280.00
8-3	Chlorine dosing machine		1	4500	4500.00	2500	2500.00	4500	4500.00	2500	2500.00	2500	2500.00	4000	4000.00
					87,700.00		94,800.00		86,250.00		89,851.90		94,800.00		97,765.00

†Advertised as Contract 8

*Contract awarded to Dravo Cont. Co. May 24, 1927.

CANVASS OF BIDS FOR CONTRACT 12† OPENED MAY 20, 1927.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
CONTRACT 12†
SINKING SHAFT NO. 4 FOR WACHUSETT COLDBROOK TUNNEL IN TOWN OF RUTLAND

				James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass.		Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa.		A. Phelps & Sons 3130 Braden St. Detroit, Mich.		Winston & Co. Inc. 240 Fair St. Kingston, N.Y.		Anthony Baruffaldi 52 Powder Ho. Blvd. Somerville, Mass.		Bruno & Petitti 18 Tremont St. Boston, Mass.		V. J. Grande 100 Academey Hill Rd. Boston, Mass.	
				Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A		Alternate A	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1-4	Earth excavation to surface of rock	Cu. Yds.	225	6.50	1,462.50	10.00	2,250.00	30.00	6,750.00	20.00	4,500.00	10.00	2,250.00	20.00	4,500.00	50.00	11,250.00
2-4	Rock excavation in shaft and tunnel	Cu. Yds.	4,200	13.45	56,490.00	13.50	56,700.00	18.50	77,700.00	20.00	84,000.00	20.00	84,000.00	25.00	105,000.00	45.00	189,000.00
3-4	Shaft and tunnel drainage	Lin. Ft.	540	9.75	5,265.00	15.00	8,100.00	2.00	1,080.00	10.00	5,400.00	15.00	8,100.00	10.00	5,400.00	20.00	10,800.00
4-4	Forms for concrete lining	Lin. Ft.	430	15.75	6,772.50	20.00	8,600.00	12.00	5,160.00	10.00	4,300.00	10.00	4,300.00	10.00	4,300.00	20.00	8,600.00
5-4	Concrete lining	Cu. Yds.	1,100	11.55	12,705.00	15.00	16,500.00	7.00	7,700.00	12.50	13,750.00	15.00	16,500.00	30.00	33,000.00	20.00	22,000.00
6-4	Portland cement	Bbls.	1,700	2.70	4,590.00	3.20	5,440.00	4.00	6,800.00	3.00	5,100.00	3.00	5,100.00	4.00	6,800.00	3.50	5,950.00
7-4	Liquid chlorine	Lbs.	2000	15¢	300.00	15¢	300.00	20¢	400.00	25¢	500.00	20¢	400.00	25¢	500.00	1.50	3,000.00
8-4	Chlorine dosing machine		1	2,500	2,500.00	4,500	4,500.00	2,000	2,000.00	2,500	2,500.00	1,000	1,000.00	2,000	2,000.00	4,500	4,500.00
					90,085.00		102,390.00		107,590.00		120,050.00		121,650.00		161,500.00		252,100.00

				James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass.		Dravo Cont. Co.* Dravo Bldg. Pittsburg, Pa.		Winston & Co. Inc. 240 Fair St. Kingston N.Y.		James J. Coughlan & Sons, Inc. 27 School St. Boston, Mass.		Dravo Cont. Co. Dravo Bldg. Pittsburg, Pa.		Winston & Co. Inc. 240 Fair St. Kingston N.Y.		M. F. Gaddis 6 Beacon St. Boston. Mass.	
				Alternate B		Alternate B		Alternate B		Alternate C		Alternate C		Alternate C		Alternate C	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1-4	Earth excavation to surface of rock	Cu. Yds.	225	6.50	1,462.50	10.00	2,250.00	19.00	4,275.00	6.50	1,462.50	10.00	2,250.00	19.00	4,275.00	20.00	4,500.00
2-4	Rock excavation in shaft and tunnel	Cu. Yds.	4,200	13.45	56,490.00	13.00	54,600.00	19.00	79,800.00	13.45	56,490.00	12.50	52,500.00	19.00	79,800.00	21.00	88,200.00
3-4	Shaft and tunnel drainage	Lin. Ft.	540	9.75	5,265.00	15.00	8,100.00	10.00	5,400.00	9.75	5,265.00	15.00	8,100.00	10.00	5,400.00	5.00	2,700.00
4-4	Forms for concrete lining	Lin. Ft.	430	15.75	6,772.50	20.00	8,600.00	10.00	4,300.00	15.75	6,772.50	20.00	8,600.00	10.00	4,300.00	3.00	1,290.00
5-4	Concrete lining	Cu. Yds.	1,100	11.55	12,705.00	15.00	16,500.00	12.50	13,750.00	11.55	12,705.00	15.00	16,500.00	12.50	13,750.00	10.50	11,550.00
6-4	Portland cement	Bbls.	1,700	2.70	4,590.00	3.20	5,440.00	3.00	5,100.00	2.70	4,590.00	3.20	5,440.00	3.00	5,100.00	4.00	6,800.00
7-4	Liquid chlorine	Lbs.	2000	15¢	300.00	15¢	300.00	25¢	500.00	15¢	300.00	15¢	300.00	25¢	500.00	14¢	280.00
8-4	Chlorine dosing machine		1	2,500	2,500.00	4,500	4,500.00	2,500	2,500.00	2,500	2,500.00	4,500	4,500.00	2,500	2,500.00	4,000	4,000.00
					90,085.00		100,290.00		115,625.00		90,085.00		98,190.00		115,625.00		119,320.00

†Advertised as Contract 8

*Contract awarded to Dravo Cont. Co. May 24, 1927.

Canvass of Bids for Contract 13 Opened July 15, 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract 13

Constructing 20" Pipe Line from Whitehall Reservoir to Dam on City Brook in the Town of Hopkinton.

Item	Description	Unit	Quantity	* 1 Portland Cont. Co. Inc. 97 Exchange St. Portland, Me.		2 Mark E. Kelley 35 Foster St. Peabody, Mass.		3 R. H. Newell Co. Uxbridge, Mass.		4 Cenedella & Co. 68 School St. Milford, Mass.		5 General Cont. Co. Inc. 32 Beach Ave. Salem, Mass.		6 John H. McCusker 62 Church St. Waltham, Mass.		7 J. J. Ducey 1295 Worcester St. Framingham, Mass.		8 A. Phelps & Sons 5150 Braden St. Detroit, Mich.	
				Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1.	Connection to gatehouse at Whitehall Reservoir	Lump	Sum	450.00	450.00	646.00	646.00	750.00	750.00	1000	1000.00	1000	1,000.00	850.00	850.00	300.00	300.00	1200	1,200.00
2.	Furnishing 20" C.I. pipe and special castings	Lin. Ft	6800	4.25	28900.00	4.48	30,464.00	4.80	32640.00	4.10	27,880.00	3.90	26,520.00	6.30	42,840.00	5.60	38,000.00	7.25	49,300.00
3.	Laying 20" C.I. pipe and special castings	Lin. Ft.	6800	0.92	6,256.00	0.75	5,100.00	0.70	4,760.00	1.40	9,520.00	1.00	6,800.00	0.25	1,700.00	1.00	6,800.00	0.80	5,440.00
4.	Excavation, fill and refill	Cu Yds.	4000	2.40	9600.00	2.65	10,600.00	2.80	11,200.00	2.75	11,000.00	4.00	16,000.00	2.50	10,000.00	3.00	12,000.00	1.50	6,000.00
5.	Excavation fill and refill	Cu. Yds.	1700	1.22	2074.00	4.27	7259.00	2.70	4,590.00	4.00	6,800.00	4.00	6800.00	5.00	8,500.00	6.00	10,200.00	5.00	8,500.00
6.	Upper Mill Pond crossing	Lump	Sum	3500	3,500.00	1865	1865.00	5000	5000.00	5500	5,500.00	5000	5,000.00	3590	3,590.00	3600	3,600.00	5700	5,700.00
7.	Furnishing and constructing one 4" blowoff	Lump	Sum	25.00	25.00	182.00	182.00	150.00	150.00	100.00	100.00	150.00	150.00	150.00	150.00	160.00	160.00	90.00	90.00
8.	Furnishing and constructing one 2" air relief. Type A	Lump	Sum	23.00	23.00	125.00	125.00	150.00	150.00	200.00	200.00	150.00	150.00	160.00	160.00	125.00	125.00	90.00	90.00
9.	Furnishing and constructing one 2" air relief. Type B	Lump	Sum	135.00	135.00	250.00	250.00	900.00	900.00	200.00	200.00	300.00	300.00	290.00	290.00	230.00	230.00	210.00	210.00
10.	Excavation at the diversion dam on City Brook	Cu. Yds.	100	1.50	150.00	2.50	250.00	5.00	500.00	4.00	400.00	4.00	400.00	5.00	500.00	4.00	400.00	2.00	200.00
11.	Furnishing and placing impervious core and blanket in diversion dam	Cu. Yds.	550	1.60	880.00	1.50	825.00	2.50	1375.00	3.00	1650.00	5.00	2750.00	3.00	1,650.00	3.00	1,650.00	2.00	1100.00
12.	Furnishing and placing pervious embankment in diversion dam	Cu. Yds.	1200	1.60	1920.00	1.40	1680.00	1.75	2100.00	1.75	2100.00	4.00	4800.00	2.00	2400.00	2.50	3000.00	1.25	1,500.00
13.	Furnishing and placing soil dressing	Cu. Yds.	100	2.00	200.00	2.25	225.00	2.00	200.00	3.00	300.00	5.00	500.00	2.00	200.00	3.00	300.00	1.25	125.00
14.	Furnishing and placing concrete	Cu Yds.	30	19.00	570.00	20.00	600.00	30.00	900.00	20.00	600.00	25.00	750.00	30.00	900.00	20.00	600.00	24.00	720.00
15.	Furnishing and placing paving	Cu Yds	25	8.00	200.00	8.00	200.00	10.00	250.00	8.00	200.00	10.00	250.00	5.00	125.00	10.00	250.00	10.00	250.00
16.	Furnishing and placing 20" shear valve at pipe line outlet.	Lump	Sum	80.00	80.00	250.00	250.00	250.00	250.00	300.00	300.00	300.00	300.00	150.00	150.00	450.00	450.00	300.00	300.00
					54,963.00		60,321.00		65,715.00		67,750.00		72,470.00		74,005.00		78,145.00		80,725.00

* Contract awarded to Portland Contracting Co. Inc. July 15, 1927

Canvass of Bids for Contract 16 Opened Sept 23 1927.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract 16

For clearing and excavating open channel from diversion dam on City Brook to Hopkinton Reservoir in the town of Hopkinton.

				* 1 Sanders Eng. Co 102 Exchange St., Portland, Maine		2 Fred W Carlson 36 Shaw R'd, Bridgewater, Mass.		3 C & R Const. Co., 75 Bradein St., Roslindale, Mass.		4 Cenedella & Co., 68 School St., Milford, Mass.		5 Edward O'Toole 237 Washington St, Westwood, Mass.		6 Charles E. Horne Millbury, Mass.		7 A. G. Tomasello & Sons Inc. 250 Stuart St., Boston, Mass.	
ITEM	DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT
1.	Clearing specified areas in diversion reservoir and along line of channel.	Acre	30	270.00	8,100.00	125.00	3,750.00	300.00	9,000.00	200.00	6,000.00	200.00	6,000.00	200.00	6,000.00	200.00	6,000.00
2.	Grubbing specified areas in diversion reservoir.	Acre	8	450.00	3,600.00	275.00	2,200.00	300.00	2,400.00	350.00	2,800.00	200.00	1,600.00	800.00	6,400.00	1000.00	8,000.00
3.	For channel excavation and grading.	Cu. yd.	20,000	1.10	22,000.00	1.50	30,000.00	1.50	30,000.00	1.65	33,000.00	1.95	39,000.00	1.90	38,000.00	2.40	48,000.00
4.	For gravel fill in channel and highways.	Cu. yd.	500	4.00	2,000.00	3.00	1,500.00	2.50	1,250.00	4.00	2,000.00	2.50	1,250.00	2.00	1,000.00	4.00	2,000.00
5.	Furnishing and laying 30" cast iron culvert pipe.	Lin. ft.	24	15.00	360.00	15.00	360.00	25.00	600.00	15.00	360.00	12.00	288.00	15.00	360.00	20.00	480.00
6.	Furnishing and placing concrete.	Cu. yd.	30	22.00	660.00	30.00	900.00	18.00	540.00	30.00	900.00	30.00	900.00	20.00	600.00	15.00	450.00
					36,720.00		38,710.00		43,790.00		45,060.00		49,038.00		52,360.00		64,930.00

				8 Peter Saliucci 55 Pond St., Waltham, Mass.		9 Mark E Kelley Co. Inc. 35 Foster St. Peabody, Mass.		10 Anthony Ross & Son 627 Mass. Ave., Lexington, Mass.		11 Antonio Mogavero 6 Dane St., Peabody, Mass.		12 M. I. O'Connor 696 Bridge R'd Northampton Mass.		13 Raymond A. Bergesson 41 Baxter St., Woonsocket, R. I		14 George T Rendle Co 270 Condor St., East Boston, Mass. (Informal bid)	
ITEM	DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT
1.	Clearing specified areas in diversion reservoir and along line of channel.	Acre	30	500.00	15,000.00	832.00	24,960.00	300.00	9,000.00	600.00	18,000.00	825.00	24,750.00	200.00	6,000.00	800.00	24,000.00
2.	Grubbing specified areas in diversion reservoir.	Acre	8	1200.00	9,600.00	950.00	7600.00	600.00	4,800.00	1000.00	8,000.00	2,500.00	20,000.00	500.00	4,000.00	600.00	4,800.00
3.	For channel excavation and grading.	Cu. yd.	20,000	2.00	40,000.00	2.00	40,000.00	3.00	60,000.00	2.45	49,000.00	1.90	38,000.00	6.00	120,000.00	3.80	76,000.00
4.	For gravel fill in channel and highways.	Cu. yd.	500	3.00	1,500.00	2.00	1,000.00	2.00	1,000.00	3.00	1,500.00	4.20	2,100.00	5.00	2,500.00	3.00	1,500.00
5.	Furnishing and laying 30" cast iron culvert pipe.	Lin. ft.	24	30.00	720.00	15.00	360.00	15.00	360.00	15.00	360.00	18.00	432.00	3.00	72.00	48.00	1,152.00
6.	Furnishing and placing concrete.	Cu. yd.	30	40.00	1,200.00	20.00	600.00	25.00	750.00	25.00	750.00	30.00	900.00	40.00	1,200.00	16.00	480.00
					68,020.00		74,520.00		75,910.00		77,610.00		86,182.00		133,772.00		107,932.00

* Contract awarded to Sanders Eng. Co. Sept 23, 1927.

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1928, its

THIRD ANNUAL REPORT

I. Organization and Administration

There was no change in the personnel of the Commission during the year. Davis B. Keniston continued as chairman, and Charles M. Davenport and Joseph H. Soliday as associate commissioners. R. Nelson Molt continued as secretary.

The clerical force of the Commission's office at Boston has remained the same throughout the year. Three special agents were appointed during the year, who have had the care of property acquired by the Commission in the Swift River Valley and along the tunnel line. Real estate purchasing agents and conveyancers have been employed as needed.

The engineering and clerical force of the engineering department averaged 125 employees during the year, with a maximum of 133 in December, 1927.

II. Engineering Department

Frank E. Winsor continued as chief engineer, with Karl R. Kennison as designing engineer and Walton H. Sears as mechanical engineer.

Three division engineers are in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; and N. LeRoy Hammond, Swift River Reservoir Division. William W. Peabody reported on July 9, 1928, succeeding Harold W. Horne.

The Commission report with regret the death on May 23, 1928, of Harold W. Horne who, as division engineer, rendered most efficient and faithful service in the location and construction of the Wachusett-Coldbrook Tunnel.

X. H. Goodnough, Chief Engineer of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, continued as consulting engineers. Charles T. Main of Boston was employed from time to time as consulting engineer on mill and water power damages, and Doctor Charles P. Berkey of Columbia University as geologist. Other consultants were employed from time to time as needed.

III. Offices

The offices of the Commission and of the Chief Engineer continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston. The three division offices for the Wachusett-Coldbrook Tunnel, the Coldbrook-Swift Tunnel and Swift River Reservoir Divisions continued at Holden Center, Hardwick Center and Enfield, respectively. The office in Framingham for the Southern Sudbury Emergency Supply was discontinued. A laboratory for water analysis has been established.

IV. Real Estate

Within the Swift River watershed a total of 1,210 applications by the owners of real estate seeking to dispose to the Commission of a total of 50,119 acres have been received, and of this acreage the Commission has concluded the purchase of, or has under option a total of 26,954 acres. Further details appear in the attached tables.

Land along the route of the Wachusett-Coldbrook tunnel has been acquired, and also, for future sanitary protection, areas in the vicinity of the village of Coldbrook in the towns of Oakham and Barre.

For land taken in fee and for easements taken on account of the Southern Sudbury Emergency Supply settlements were made in all but a few cases.

V. Town of Prescott

Under the provisions of Chapter 340 of Acts of 1928, the Commission was required by the Legislature to assume direction of the town government of the town of Prescott during the remainder of the town's corporate existence. The provisions of the Act were accepted by the town of Prescott on June 25, 1928, and within the time required by the Act the Commission duly appointed agents for carrying on the town affairs in the exercise of the authority conferred upon it by the provisions of the Act.

VI. Progress

(*a*) *General.* — The United States War Department on March 19, 1928, notified the Commission that no objection would be interposed to the diversion of the flood waters of the Ware River in excess of 85,000,000 gallons daily between October 15 and June 15 of each year. The application for the diversion of the waters of the Swift River is still pending before the War Department.

On January 9, 1928, the State of Connecticut filed a bill in equity in the United States Supreme Judicial Court against the Commonwealth of Massachusetts, objecting to the diversions from the Ware and Swift rivers as authorized by Chapter 375, Acts of 1926, and Chapter 321, Acts of 1927. Hon. Bentley W. Warren of Boston was appointed by the Attorney-General as Special Assistant Attorney-General in the case.

(*b*) *Ware River Supply.* — The contracts for the construction of the shafts on the Wachusett-Coldbrook Tunnel were continued until April 30, 1928, when contracts were let for the tunnel construction. 17,331 feet or 3.28 miles of tunnel has been excavated. Shaft 1 at outlet works to the Wachusett Reservoir is partly excavated, and the Ware River intake works near the village of Coldbrook have been partly completed.

(*c*) *Swift River Supply.* — Real estate and topographical surveys were continued throughout the year. Work was continued on the census of burials in cemeteries, together with records of inscriptions on head stones and monuments. Upon request some bodies have been removed from the reservoir area and have been interred in other cemeteries.

(*d*) *Southern Sudbury Emergency Supply.* — Construction on the Southern Sudbury Emergency Supply was finished early in the fiscal year.

VII. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

VIII. Other Reports

The report of the Chief Engineer is herewith presented. It includes a summary of the information of geological interest, in accordance with the requirements of Section 2 of Chapter 321 of the Acts of 1927.

Respectfully submitted,

DAVIS B. KENISTON,
CHARLES M. DAVENPORT,
JOSEPH H. SOLIDAY,
Metropolitan District Water Supply Commission.

24 School Street, Boston, Massachusetts,
January 14, 1929.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1928.

ORGANIZATION

In numbers the engineering organization has not materially changed during the year.

Karl R. Kennison, Designing Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, the preparation of contract specifications, contract and working drawings.

Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. He assists in the design of work of a mechanical engineering nature and in the preparation of contract specifications.

Three Division Engineers are in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Swift River Reservoir Division. William W. Peabody reported on July 9, 1928, succeeding Harold W. Horne, who died on May 23, 1928.

Walter Knowles, Assistant Engineer, had charge of the field work for the Southern Sudbury Emergency Supply until that work was completed, when he was transferred to the Swift River Reservoir Division.

Walter H. Junkins, Chemist, has charge of the Springfield Laboratory.

X. H. Goodnough, Chief Engineer, of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, continued as Consulting Engineers. Charles T. Main, consulting engineer, of Boston, has reported on mill and water power damages. Dr. Charles P. Berkey, of Columbia University, has advised on all geological matters. Other experts were employed from time to time as required.

The employees under the direction of the Chief Engineer at the end of the year and of the preceding year were as follows:

PERSONNEL OF ENGINEERING DEPARTMENT

CLASSIFICATION	Nov. 30, 1927	Nov. 30, 1928
HEADQUARTERS OFFICE, CHIEF ENGINEER AND DESIGNING DIVISION:		
Chief Engineer	1	1
Designing Engineer	1	1
Mechanical Engineer	1	1
Assistant Engineers	9	11
Draftsmen	6	9
Instrumentmen	1	2
Rodmen	2	–
Senior Stenographer	1	1
Stenographers	3	3
Clerks	2	2
File Clerk	1	1
Office Boy	1	1
	29	33
HOLDEN OFFICE, WACHUSETT–COLDBROOK TUNNEL DIVISION:		
Division Engineer	1	1
Assistant Engineers	5	5
Draftsmen	2	2
Instrumentmen	4	5
Rodmen	10	5
Axemen	3	4
Inspectors	7	8
Stenographer	1	1
	33	31

Classification	Nov. 30, 1927	Nov. 30, 1928
Hardwick Office, Coldbrook–Swift Tunnel Division:		
Division Engineer	1	1
Assistant Engineers	2	5
Draftsmen	–	1
Instrumentmen	3	1
Rodmen	8	8
Axemen	2	4
Inspectors	–	1
	16	21
Enfield Office, Swift River Reservoir Division:		
Division Engineer	1	1
Assistant Engineers	7	9
Draftsmen	1	3
Instrumentmen	5	7
Rodmen	16	11
Axemen	6	7
Inspectors	1	1
Clerk	1	–
	38	39
Framingham Office, Southern Sudbury Emergency Supply:		
Assistant Engineers	4	–
Instrumentmen	3	–
Rodmen	4	–
Axemen	2	–
Inspectors	4	–
	17	–
Springfield Laboratory:		
Chemist	–	1
Assistant Engineer	–	1
Assistant Chemist	–	1
Instrument men	–	1
Boatman	–	1
Clerk	–	1
	–	6
Total Engineering Force	133	130

The maximum force during the year was 133, during the weeks ending December 3 and 10, 1927. The minimum force was 119, during several weeks in April, May and July, 1928. The average force for the year was 125.

Offices

The office of the Chief Engineer and Designing Division was continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Swift River Reservoir Division was continued in the Felton Block at Enfield (with additional drafting room space in Bartlett Block). The field office for the Southern Sudbury Emergency Supply at 5 Hollis Street, Framingham, was discontinued on February 29, 1928. A laboratory for water analyses was established on July 23, 1928, in the Markarian Building, 175 State Street, Springfield.

Headquarters Office

Summary of the Year's Work

Applications for Diversions from Ware and Swift Rivers. — Studies of the effect of the proposed diversions for the Metropolitan District of waters from the Ware and Swift rivers upon the flow of the Connecticut River were continued. The War Department under date of March 19, 1928, advised the Commission that "no objection will be interposed by the War Department to the diversion of the flood waters of the Ware River exceeding 85,000,000 gallons per day for the period October 15 to June 15 each year."

The Commission's application to divert the waters of the Swift River as authorized by Chapter 321, Acts of 1927, is still pending.

Diversion Damages. — Hydrographic data were gathered at various plants which may be affected by the proposed diversions and elsewhere, for use in connection with the determination of diversion damages.

Real Estate. — In the Swift River Reservoir area, 17,917 acres were offered for sale by their owners this year, making a total so offered to date of 50,119 acres. Reports and recommendations with respect to purchasing these various parcels were submitted to the Commission. Preliminary studies were continued of highway and cemetery relocations.

One taking plan covering 11 parcels of land along a portion of the Wachusett-Coldbrook Tunnel was prepared and filed during the year.

Contracts and Specifications. — Contract 14, for the construction of the East Portion of the Wachusett-Coldbrook Tunnel in the towns of West Boylston, Holden and Rutland, and Contract 17, for the construction of the West Portion of the Wachusett-Coldbrook Tunnel in the towns of Rutland, Oakham and Barre, were executed on April 30, 1928. Contract 14 includes Shaft 1, 221 feet deep, at the outlet into Wachusett Reservoir, and Contract 17 includes Shaft 8, 253 feet deep, at the Ware River Intake. The total length of the tunnel in these two contracts, including short portions excavated near the bottom of six construction shafts under other contracts, is about 14 miles. As the work progressed, working drawings were prepared and issued as required.

Plans and specifications were prepared for furnishing cast iron shaft lining plates and other special castings to be incorporated in the construction of the Ware River Intake Works at Shaft 8.

Plans and specifications are in progress for the diversion dam and gatehouse of the Ware River Intake Works and studies were made for the extension of the tunnel westerly from Coldbrook to the proposed Swift River Reservoir.

Inspection and Tests. — E. L. Conwell & Company of Philadelphia continued to make tests of cement for use on the work. As the demand for cement increased with the progress of Contracts 14 and 17, bins were set aside at the cement mills for use on these contracts. Bin sampling was then substituted for car sampling. Four bins, aggregating 27,000 barrels of cement, were tested. As each carload is shipped, an inspector certifies that the contents are from an approved bin.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook which was established in co-operation with the United States Geological Survey was completed and put into operation January 28, 1928. During the year measurements of flow were made to establish a rating curve, and the daily record of stream flow was computed.

A gaging station was established on the Chicopee River at Bircham Bend at the plant of the United Electric Light Company of Springfield in co-operation with the same company. A recording gage was installed by the Commission and put into operation on August 4, 1928. Field work was done to determine the rating curves for the discharge of the wheels and the dam, which work is still in progress.

A stream gaging station was established by the United States Geological Survey on the Connecticut River at Thompsonville, Connecticut, "Enfield Dam," July 15, 1928, in which work the Commission was one of the co-operating parties. At this station, current meter measurements were made in co-operation with the United States Geological Survey to determine the rating curve of the dam and the canal. Staff gages were established on the Connecticut River from the Massachusetts state line to Holyoke, and various current meter measurements were made at points on the Swift, Ware, Quaboag and Chicopee rivers.

Design of Structures

Shaft 1. Outlet to Wachusett Reservoir. — Further studies of the tunnel discharge under various conditions out of Shaft 1 and through the channel to the Wachusett Reservoir were made in connection with the preparation of working drawings for Contract 14. The final design provides a weir for measurement of all flows too small to be measured by the large Venturi meter to be imbedded in the lining of the shaft itself.

Studies were also made of the superstructure and power plant and equipment that may later be provided at this location, also of the valves that must be in-

stalled as soon as the Swift River Reservoir is ready for filling, in order to turn the Ware flood flows westerly, when desired, into the Swift River Reservoir instead of allowing them to flow easterly into Wachusett Reservoir.

Due to an exceptionally heavy summer and autumn rainfall in 1927 and a consequent unforeseen rise in the Wachusett Reservoir in the latter part of 1927 which was maintained well into 1928, the sanitary works which the tunnel contractor was required to provide at Shaft 1 were redesigned and built to provide for operation on a higher level.

Shaft 8. Ware River Intake Works. — Studies of the diversion works required at Shaft 8 were continued and detailed designs are in progress for the complete intake works that will be required for the Ware River at Coldbrook.

The flow down the river will be measured and recorded by a 52″ x 26″ Venturi meter, to the limit of its capacity. An adjustable orifice or weir will be used to limit the discharge of the river to the required 85 million gallons daily. Flood flows in excess of this limit will be automatically discharged into the tunnel through a battery of siphon spillways with crest sections varying in size from 24″ pipe to 9 feet long x 3 feet 3 inches high. Floods up to about 700 cubic feet per second will be measured through a 120″ x 60″ Venturi meter, and greater floods will automatically discharge freely into the shaft up to the maximum capacity of the tunnel, estimated at 2,800 cubic feet per second when discharging into both Wachusett and Swift River Reservoirs.

Southern Sudbury Emergency Supply. — The construction of the Southern Sudbury Emergency Supply was completed and the pipe lines tested for capacity during the year. Tests of these lines confirmed the information relative to capacities of the various lines given in the Annual Report of the Chief Engineer for the year ending November 30, 1927.

Record drawings covering the construction of the Southern Sudbury Emergency Supply were prepared and turned over to the Chief Engineer of the Water Division of the Metropolitan District Commission.

Wachusett-Coldbrook Tunnel Division — Holden Office

The Wachusett-Coldbrook Tunnel Division has charge of the construction of the Wachusett-Coldbrook Tunnel, with the exception of Shaft 8. The division office was continued at Holden Center and field offices were provided at each shaft where work was in progress under Contracts 14 and 17.

Following the death of Harold W. Horne on May 23 and until William W. Peabody reported on July 9 to succeed him as Division Engineer, the work of the Division was in charge of Richard R. Bradbury, the Division Engineer of the Coldbrook-Swift Tunnel Division.

Office Work

Topographic notes were reduced and plotted, real estate surveys computed and plotted and estimates prepared. Studies were made of geologic formations as revealed by shaft and tunnel excavation, of the character of materials available for concrete aggregates and of sands available for filters. Records of contractor's equipment on Contracts 14 and 17, including camps and appurtenances were kept.

Compressive tests were made on concrete test cylinders cast at the outlet works at Shaft 1. These tests were made at the Worcester Polytechnic Institute.

Field Work

In the vicinity of Coldbrook, 52 parcels of land totalling 635 acres were surveyed. Additional real estate surveys were made in Rutland and Holden. Topographic surveys totalling about 600 acres were made at Shaft 1 and along the Ware River from Coldbrook to a point approximately two miles north. A line of levels was run from the precise bench at Shaft 6 to North Rutland. A total of 33 property bounds were set. Lines and grades were given for construction work on the Wachusett-Coldbrook Tunnel under Contracts 4, 8, 12, 14 and 17.

Beginning September 21, 1928, color observations were made weekly at a number of stations along the Ware River and tributary streams. Samples of the drinking water used at the different contractor's camps and of the effluent from the

sewage disposal plants at various institutions in Rutland were taken by the State Department of Health, with the co-operation of this office, for analysis by that department.

Progress of Contracts

Continuing under an agreement dated July 15, 1927, with the Pennsylvania Drilling Company, for making core borings, six holes totalling about 290 feet were drilled during the year. Five of these were for location studies of the proposed Coldbrook-Swift Tunnel, four holes in Barre along the line just west of Shaft 8 and one in Hardwick for locating Shaft 10. The sixth hole was placed at the site of the diversion dam at Shaft 8 to obtain additional information regarding earth cover and rock conditions at this location. These six holes totalled 206.5 feet in earth and 84.0 feet in ledge, making the total under this agreement 2,176.2 feet in earth and 552.5 feet in ledge.

Two gas-driven drilling machines were used on this work. Representative samples of the overburden were obtained at intervals with the aid of a dry sampling spoon and a sample or core of the underlying rock was obtained by drilling to a suitable depth with a black diamond-studded bit.

The work under this agreement was completed December 19, 1927.

Contract 4. — Contract 4 for sinking Shaft 5 (656 feet deep) of the Wachusett-Coldbrook Tunnel was awarded to James J. Coughlan & Sons, Inc., of Boston, Mass., on March 28, 1927. The work was completed on June 12, 1928, the total value thereof being $290,581.99.

At the beginning of the year, this shaft had been excavated to a point 8 feet above the tunnel invert and 633 linear feet of shaft lining had been completed. Early in the year, tunnel excavation was started, maintaining a top heading of about one-half the tunnel cross section 10 feet to 20 feet in advance of the bench excavation. The average weekly progress on tunnel excavation easterly was 29.1 feet and westerly 30.3 feet, the maximum progress being in the week ending March 17, 1928, when 45 feet was excavated in the east section and 51 feet in the west section. No timbering was required. At the termination of the contract the excavation had reached an average distance of 670.5 feet east of the shaft and 696.5 feet west of the shaft, making a total of 1,367 feet. At the conclusion of the contract, pumpage was at the rate of 32 gallons per minute.

The work done and materials furnished under the principal items of this contract (Shaft 5) were as follows:

	During Year ending Nov. 30, 1928	Total
Earth excavation (19 ft.)	–	177.2 cu. yds.
Rock excavation in shaft (637 ft.) and tunnel (1,345 ft.)	9,310.7 cu. yds.	14,336.7 cu. yds.
Drainage in shaft and tunnel	1,693.1 lin. ft.	2,017.1 lin. ft.
Forms for shaft lining	–	633 lin. ft.
Concrete for shaft lining (633 ft.)	–	1,428.2 cu. yds.
Portland cement	–	1,754 bbls.

The contractor's total force averaged 76 men.

Contract 8. — Contract 8 for sinking Shafts 6 and 7 of the Wachusett-Coldbrook Tunnel was awarded to James J. Coughlan & Sons, Inc., of Boston, Mass., on May 24, 1927. The top heading and bench method was employed in driving tunnel from both shafts under this contract. The work was completed on June 12, 1928, the total value thereof being $456,784.26.

Shaft 6 (432 feet deep). — At the beginning of the year Shaft 6 had already been excavated to a point 6 feet above the tunnel invert and the concrete lining had been completed. Shaft excavation was finished early in the year and tunnel excavation started at both east and west headings. The average weekly progress on tunnel excavation was 29.2 feet in an easterly, and 29.1 feet in a westerly direction. The maximum progress of 47 feet easterly and 50.5 feet westerly was for the week ending February 11, 1928. At the termination of the contract the excavation had reached an average distance of 671 feet east and 669 feet west of the shaft, totalling 1,340 feet. No timbering was required. At the conclusion of the contract, pumpage was about 18 gallons per minute.

The work done and materials furnished under the principal items of the contract at Shaft 6 were as follows:

	During Year ending Nov. 30, 1928	Total
Earth excavation (29 ft.)	–	273.3 cu. yds.
Rock excavation in shaft (403 ft.) and tunnel (1,318 ft.)	9,166 cu. yds.	12,340 cu. yds.
Drainage in shaft and tunnel	1,554.2 lin. ft.	1,765.2 lin. ft.
Forms for concrete lining	–	413 lin. ft.
Concrete shaft lining (413 ft.)	–	960 cu. yds.
Portland cement	–	1,054 bbls.

The contractor's total force averaged 66 men.

Shaft 7 (411 feet deep). — At the beginning of the year Shaft 7 had been completely excavated and lined and the tunnel had been excavated for a distance of 123 feet easterly and 128 feet westerly. The average weekly progress in both easterly and westerly directions was 33.2 feet with a maximum of 51.5 feet at the east heading and 51 feet at the west heading for the week ending March 24, 1928. At the end of the contract an average distance of 861 feet was reached in each direction, making a total of 1,722 feet, 1,471 of which was done this year. No timbering was required. The pumpage at the conclusion of the contract was about 18 gallons per minute.

The work done and materials furnished under the principal items of the contract at Shaft 7 were as follows:

	During Year ending Nov. 30, 1928	Total
Earth excavation (24 ft.)	–	230.9 cu. yds.
Rock excavation in shaft (387 ft.) and tunnel (1,700 ft.)	9,881 cu. yds.	14,650 cu. yds.
Drainage in shaft and tunnel	1,802.3 lin. ft.	2,126.3 lin. ft.
Forms for concrete lining	–	392 lin. ft.
Concrete shaft lining (393 ft.)	–	908 cu. yds.
Portland cement	–	1,105 bbls.

The contractor's total force averaged 67 men.

Contract 10. — Contract 10 with the New England Power Company, for constructing, maintaining and operating a 22,000-volt transmission line along the Wachusett-Coldbrook Tunnel line, was in force throughout the year. The contractor employed an average of seven men. Electric power was purchased from this company by the contractors on Contracts 4, 8, 12, 14 and 17.

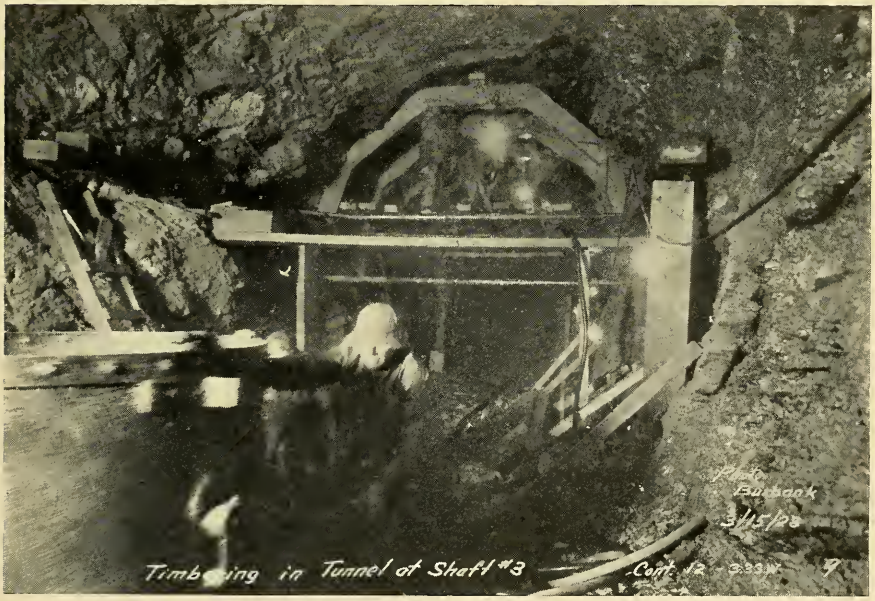
The cost of operation and maintenance for the twelve months ending November 30, 1928, was $8,166.86.

Contract 12. — Contract 12, with the Dravo Contracting Company of Pittsburgh, Pa., for sinking Shafts 2, 3 and 4 of the Wachusett-Coldbrook Tunnel, was modified on October 25, 1927, and January 3, 1928, to provide for extending the tunnel beyond the limits set forth in the contract. The total length of tunnel excavated under this contract was 3,809.5 feet, of which 3,366.5 feet was done this year. The top heading and bench method of tunnelling was employed at all three shafts. The work was completed on June 12, 1928, the total value thereof being $632,727.44.

Shaft 2 (313 feet deep). — At the beginning of the year, the excavation and lining at Shaft 2 had been completed and the tunnel had been excavated for a distance of 213 feet easterly and 230 feet westerly. The average weekly excavation was 29.4 feet easterly and 30.5 feet westerly with a maximum weekly progress of 43 feet easterly and 34 feet westerly during the week ending April 21, 1928. At the termination of the contract, the excavation had reached an average distance of 867.5 feet east and 902.5 feet west of the shaft, making a total of 1,770 feet, 1,327 feet of which was done this year. No timbering was required. At the conclusion of the contract, pumpage was at the rate of about 64 gallons per minute.

The work done and materials furnished under the principal items of the contract at Shaft 2 were as follows:

Contract 12. — Spoil Bank at Shaft 2.



Contract 12. — Timbering in the Tunnel at Shaft 3.

	During Year ending Nov. 30, 1928	Total
Earth excavation (25 ft.)	–	231.8 cu. yds.
Rock excavation in shaft (289 ft.) and tunnel (1,748 ft.)	8,998.3 cu. yds.	14,327.3 cu. yds.
Drainage in shaft and tunnel	1,707.9 lin. ft.	2,076.9 lin. ft.
Forms for concrete lining	–	291.1 lin. ft.
Concrete shaft lining (296 ft.)	–	678.2 cu. yds.
Portland cement	–	920 bbls.

The contractor's total force averaged 54 men.

Shaft 3 (339 feet deep). — At the beginning of the year Shaft 3 had been excavated to within 4 feet of the tunnel invert. The shaft was completed and tunnel excavation started early in December. A weekly average of 26.9 feet easterly and 24.3 feet westerly was excavated, with a maximum progress of 47 feet easterly and 44.5 feet westerly in the week ending April 21, 1928. At the completion of the contract, the excavation had reached an average distance of 630 feet east and 566 feet west of the shaft, a total of 1,196 feet.

Due to some disintegration and scaling of the rock in portions of the tunnel roof, permanent timber was erected in four short sections, two of which, totalling 148 feet, were east of the shaft and two, totalling 176 feet, west of the shaft. Temporary timbering for a distance of 33 feet in the tunnel east of the shaft and 34 feet west of the shaft, was also erected. Approximately 162 cubic yards of dry packing was placed above the permanent timbering. At the completion of the contract, pumpage was at the rate of about 210 gallons per minute.

The work done and materials furnished under the principal items of the contract at Shaft 3 were as follows:

	During Year ending Nov. 30, 1928	Total
Earth excavation (61 ft.)	–	693.4 cu. yds.
Rock excavation in shaft (278 ft.) and tunnel (1,174 ft.)	7,954.3 cu. yds.	10,348.3 cu. yds.
Drainage in shaft and tunnel	1,362.6 lin. ft.	1,528.6 lin. ft.
Forms for concrete lining	0.6 lin. ft.	327.6 lin. ft.
Concrete shaft lining (328 ft.)	–	955.3 cu. yds.
Portland cement	–	1,258¼ bbls.
Timber (391 ft.)	48.33 M ft. B. M.	48.33 M ft. B. M.
Dry packing	161.7 cu. yds.	161.7 cu. yds.

The contractor's total force averaged 58 men.

Shaft 4 (458 feet deep). — At the beginning of the year Shaft 4 had been excavated to a point 17 feet above the invert of the tunnel. The shaft was completed and weekly tunnel excavation progress thereafter averaged 22.2 feet easterly and 20.5 feet westerly, with a maximum progress of 33 feet easterly and 29.5 feet westerly during the week ending March 24, 1928. At the end of the contract the excavation had reached an average distance of 442 feet east and 401.5 feet west of the shaft, or a total of 843.5 feet. At the conclusion of the contract the pumpage was about 110 gallons per minute.

The work done and materials furnished under the principal items of the contract at Shaft 4 were as follows:

	During Year ending Nov. 30, 1928	Total
Earth excavation (23 ft.)	–	214.9 cu. yds.
Rock excavation in shaft (435 ft.) and tunnel (821.5 ft.)	5,876.3 cu. yds.	9,192.3 cu. yds.
Drainage in shaft and tunnel	1,074.7 lin. ft.	1,294.7 lin. ft.
Forms for concrete lining	0.6 lin. ft.	441.6 lin. ft.
Concrete shaft lining (442 ft.)	–	1,021.6 cu. yds.
Portland cement	130 bbls.	1,544 bbls.
Drilling holes in rock	581 ft.	945 ft.
Grout	22.9 cu. yds.	36.9 cu. yds.

The contractor's total force averaged 51 men.

Wachusett-Coldbrook Tunnel Contracts. — Both Contracts 14 and 17 were assigned, upon execution on April 30, 1928, to the West Construction Co., a

Massachusetts corporation organized by the contractors for the prosecution of the work, and operations were commenced early in May. General headquarters were established at West Rutland, in several buildings previously purchased by the Commission from the Rutland Worsted Co. The Wachusett-Coldbrook Tunnel Division has supervision of construction of both of these contracts except the work at Shaft 8, which is under the supervision of the Coldbrook-Swift Tunnel Division. Power for these contracts is taken from the electrical transmission line connecting all shafts constructed and maintained by the Commission under Contract 10, for which power the contractor pays the New England Power Company 1½ cents per kilowatt hour measured at 22,000 volts, as provided under the terms of said Contract 10. Pumping at Shafts 2, 3 and 4, was taken over from the former contractor on May 7. Shaft timbering for and the installation of cages in the completed shafts was begun promptly thereafter. Cross timbers consisted of one 6″ x 10″ and two 4″ x 10″ timbers spaced 10′ on centers and so placed as to form two 8′–4″ x 4′–10″ clear openings to accommodate the cages. Cage guides were of 4″ x 6″ timbers. The contractor retained four local physicians to render medical and surgical attendance to employees and perform other services as specified in the contract.

Contract 14. — Contract 14, including the east portion of the Wachusett-Coldbrook Tunnel in West Boylston, Holden and Rutland, and the construction of Shaft 1 with Outlet Works to Wachusett Reservoir, was executed on April 30, 1928, with Johnston P. Porter, R. Frederick Porter and Lawrence T. Porter, individually and as co-partners doing business under the firm name and style of J. P. Porter & Sons, who assigned the contract to the West Construction Co. Shafts 2, 3 and 4 were sunk to tunnel grade and 3,809 feet of tunnel excavated previously under Contract 12, leaving about 29,895 feet of tunnel and Shaft 1, 221 feet deep, to be driven under Contract 14. In order to avoid any possibility of contamination of the water supply in Wachusett Reservoir, this contract also included the construction of sanitary and drainage structures at each shaft. Chemical toilets were used for human excreta and the garbage was incinerated. During the year the excavation and preliminary lining of Shaft 1 were about three quarters completed, nearly half the masonry in the Outlet Channel walls was placed and a total length of 2,648 feet of tunnel was excavated. The value of the work done on this contract to November 15, the date of the latest estimate, was $268,500.15, of which 90 per cent was approved for payment.

Shaft 1. — Operations were started at Shaft 1 during the week ending June 2, with the construction of camp buildings near the shaft. The camp site is located about 350 feet south of the shaft and at a considerably higher elevation. The camp buildings include dining room and kitchen, two bunk houses, an emergency hospital, cook's quarters, drying house and storeroom. Wash water and other liquid wastes were disposed of in septic tanks, the effluent leeching into porous ground located in the drainage area of the settling basin. The buildings at the shaft include a general office, engineers' office, compressor house, garage, blacksmith shop and cement shed. The construction of the sanitary works was begun early in July. The embankment of the settling basin was constructed of earth with a compacted soil core, most of the material being obtained from excavations for the shaft and outlet channel. All water pumped from the shaft and other excavations flows into the settling basin. Chlorinating apparatus for treating the overflow from the settling basin was completed ready for operation on July 20.

The shaft excavation was taken out to natural slopes to a depth of 21 feet when a crib of 12″ x 12″ timbers surrounded by steel sheet piling was erected and sunk to rock as the excavation progressed, the sheeting being driven with a steam hammer. At the end of the year 129 feet of shaft excavation in rock had been driven, the total depth including earth being 159 feet. The preliminary concrete lining in the shaft was placed behind wooden forms made up in 6-foot units. Natural sand and gravel, delivered by motor trucks, was used for concrete. The pumpage from the shaft averaged about 25 gallons per minute until a depth of about 135 feet was reached, when it increased to 90 gallons per minute.

Excavation for the outlet channel was carried on in connection with the shaft

Contract 14. — Shaft 1 and Outlet Channel into Wachusett Reservoir.

Contract 14. — Settling Basin for Camp Sanitary Works, Shaft 2.

excavation and the entire north retaining wall was built up to or above Elevation 389. The south wall was started.

Miscellaneous Construction Data, Shaft 1

Total depth of shaft	221 feet
Depth of earth	30 feet
Work begun	June 1, 1928
Earth excavation completed	Sept. 8, 1928
Rock excavation begun	Sept. 10, 1928
Maximum depth of rock excavated in one week	20 feet
First concrete lining placed	Sept. 17, 1928

The principal items of plant at Shaft 1 were as follows:

1 Air compressor, 642 cu. ft. per min. capacity, run by 125 H. P. motor.
1 14′–0″ x 4′–6″ air receiver tank.
1 Gasoline driven drag line excavator with caterpillar traction.
1 3½-ton gasoline locomotive, 36-inch gauge, cars, etc.
1 Concrete mixer, capacity ½ yard, 7½ H. P. motor.
1 Steam hoist and boiler.
1 Derrick with 50-foot boom.
5 Pumps, the largest of which has a rated capacity of 300 gals. per min. under 275-foot head, driven by 40 H. P. motor.
Drill equipment, machine shop equipment, etc.

Shaft 2. — Work at Shaft 2 under Contract 14 was started on May 14, 1928, with the construction of camp and plant buildings comprising 2 bunk houses, an emergency hospital, foremen's and mechanic's quarters, cooks' quarters, dining room, kitchen and storeroom, general office, engineers' office, charging station, blacksmith shop, machine shop, warehouse, hoist and compressor house, blower house, powder house and an incinerator. Construction work on the dikes for settling basins and filters and shaft timbering was begun in June. The dikes of the settling basins were constructed of earth with a compacted soil core. Two sand filter beds were constructed, each of about 4,000 square feet area. The settling basin and chlorinating plant was completed and a chlorinator installed ready for use on November 12.

On August 25, drilling was started at the west heading. The tunnel from this shaft was excavated by a full face heading. Mucking was done with mucking machines. The average weekly progress on tunnel excavation was 67.5 feet easterly and 72.7 feet westerly, with a maximum progress of 78.5 feet in the east section and 94.5 feet in the west section for the week ending September 29. At the end of the year the excavation under this contract at Shaft 2 was 742.5 feet easterly and 1,018.5 feet westerly, making a total of 1,761 feet. Pumpage from the tunnel at the end of the year was at the rate of about 194 gallons per minute.

The principal items of plant at Shaft 2 were as follows:

3 Air Compressors, each of 642 cu. ft. per min. capacity, run by 125 H. P. motors.
1 Small air storage tank.
1 14′–0″ x 4′–6″ air receiver tank.
1 Drum hoist with 100 H. P. motor.
1 Blower rated at 4,000 cu. ft. of free air per min., run by 60 H. P. motor.
1 3½-ton gasoline locomotive, friction drive, 36-inch gauge.
4 5-ton storage battery locomotives, 36-inch gauge.
1 Motor-generator set; 27 K. W. generator, 40 H. P. motor.
3 Mucking machines, 36-inch gauge.
9 Pumps, the largest of which has a rated capacity of 290 gals. per min. under 320-foot head, driven by 40 H. P. motor.
1 50-foot timber head-frame and equipment.
Cars, machine shop equipment, drill equipment, etc.

Shaft 3. — Except to keep the tunnel pumped free of water there was no work done at this shaft during the year under Contract 14. The average pumpage at the end of the year was approximately 210 gallons per minute.

The principal items of plant at Shaft 3 were as follows: —

1 Single drum mine hoist with 100 H. P. electric motor.
1 Centrifugal pump rated at 290 gals. per min. under 365-foot head, run by 50 H. P. motor.
1 Two-stage 4″ centrifugal pump with 60 H. P. motor.
1 Steel head-frame, and appurtenant hoisting equipment.

Shaft 4. — Work at Shaft 4 under Contract 14 was begun during the week ending June 2, 1928, with the construction of camp and plant buildings consist-

ing of 3 bunk houses, one cottage, cook's living quarters, kitchen and mess hall, contractor's office and emergency hospital, wash house, engineers' office, hoist and compressor house, blower house, blacksmith shop, battery charging house, machine shop and storehouse, oil storage house and powder house. Construction of the settling basin dikes was begun on July 16, timbering of the shaft on August 13, drilling in the east heading on October 9 and in the west heading on October 20.

The tunnel was excavated with a full face heading until about the middle of November when the top heading and bench method was employed. The weekly progress on tunnel excavation averaged 66.0 feet easterly and 59.8 feet westerly with a maximum of 86.5 feet easterly and 73 feet westerly on the week ending December 1. At the end of the year the excavation under this contract at Shaft 4 was 528.5 feet easterly and 359 feet westerly, making a total of 887.5 feet. Pumpage at the end of the year was at the rate of about 190 gallons per minute.

The principal items of plant at Shaft 4 were as follows:

3 Air compressors, each of 642 cu. ft. per min. capacity, run by 125 H. P. induction motors.
1 Small air storage tank.
1 14′-0″ x 4′–6″ air receiver tank.
1 Drum hoist with 100 H. P. motor.
1 Blower rated at 4,000 cu. ft. of free air per min., run by 60 H. P. motor.
5 5-ton storage battery locomotives, 36-inch gauge.
1 Motor-generator set; 27 K. W. generator, 40 H. P. motor.
3 Mucking machines, 36-inch gauge.
2 Centrifugal pumps, each rated at 300 gals. per min., 490-foot head, run by 75 H. P. motors.
1 50-foot timber head-frame and equipment.
Cars, machine shop equipment, drilling equipment, etc.

The work done and materials furnished under the principal items of Contract 14 were as follows:

	Shaft 1	Shaft 2	Shaft 3	Shaft 4
Earth excavation for shafts (cu. yds.)	970	–	–	–
Rock excavation in shafts, and in tunnel within 50′ of shafts (cu. yds.)	1,886	–	–	–
Excavation in tunnel, except within 50′ of shafts (cu. yds.)	–	11,663	–	5,964
Shaft & tunnel drainage (lin. ft.)	158	1,761	–	887
Forms for preliminary concrete lining, Shaft 1 (lin. ft.)	132	–	–	–
Concrete masonry in shafts (cu. yds.)	776	–	–	–
Concrete masonry not in shafts or tunnel (cu. yds.)	1,158	27	–	17
Portland cement (bbls.)	3,160	35	–	25
Earth excavation except for shafts (cu. yds.)	7,510	2,260	–	5,616
Rock excavation except in shafts or tunnel (cu. yds.)	423	35	–	771
Refilling and embankment (cu. yds.)	4,190	6,220	–	4,193
The contractor's total force averaged (men)	31	70	3	54

Contract 17. — Contract 17, for the west portion of the Wachusett-Coldbrook Tunnel in Rutland, Oakham and Barre, and including the construction of Shaft 8, 253 feet deep, at the site of the Ware River Intake Works, was executed on April 30, 1928, with Johnston P. Porter, R. Frederick Porter and Lawrence T. Porter, individually and as co-partners doing business under the firm name and style of J. P. Porter & Sons, and James J. Coughlan & Sons, Inc., who likewise assigned the contract to the West Construction Co. At the time the contract was let, Shafts 5, 6 and 7 had been sunk to tunnel grade and 4,429 feet of tunnel had been excavated under Contracts 4 and 8. Shaft timbering was started immediately.

Garbage was taken away by local farmers, sink wastes were disposed of in septic tanks, the effluent leeching into porous ground, and human excreta were incinerated, except at Shaft 7, where plumbing fixtures draining to the same cesspools as the sink drainage were used.

The top heading and bench method was finally employed in driving tunnel at all shafts. Mucking was done both by hand and by mechanical muckers and at the end of the year 6,171.5 feet of tunnel had been excavated under this contract in this division. The value of the work done on this contract to November 15, the date of the latest estimate, was $491,603.64 of which 90 per cent was approved for payment.

Shaft 5. — During the week ending May 19, 1928, work on camp construction and timbering of the shaft was started. The camp buildings include mess hall

Contract 14. — Head Frame at Shaft 4, Spoil Bank in Background.

Contract 14. — Track Turn-outs in the Tunnel at the Bottom of Shaft 2.

and kitchen, 5 bunk houses, 1 cottage, dry house and emergency hospital. The buildings at the shaft include general office, engineers' office, hoist room and compressor house, 2 mule sheds, blower house, blacksmith shop and supply room. Tunnel excavation was started on September 10. The average weekly progress on tunnel excavation was 78.7 feet easterly and 81.8 feet westerly with a maximum, during the week ending December 1, 1928, of 86.5 feet easterly and 93.0 feet westerly. At the end of the year the excavation under this contract at Shaft 5 was 956.0 feet in the section east of the shaft and 1,000.0 feet in the west, a total of 1,956.0 feet. Temporary timbering was placed in the easterly section for a length of about 71 feet. At the end of the year, pumpage was at the rate of about 73 gallons per minute.

The principal items of plant at Shaft 5 were as follows:

3 Air compressors, with a combined capacity of 1,702 cu. ft. per min., the largest of which has a capacity of 642 cu. ft. per min. and is run by 100 H. P. motor.
1 Hoist, run by 150 H. P. motor.
1 Blower, rated at 4,000 cu. ft. of free air per min., run by 60 H. P. motor.
1 10′–0″ x 3′–6″ air receiver tank.
3 Mucking machines.
4 Pumps, the largest of which is rated at 300 gals. per min. under 670-foot head, run by 100 H. P. motor.
1 50-foot timber head-frame and equipment.
Cars, machine shop equipment, drilling equipment, etc.

Shaft 6. — During the week ending May 19, 1928, work was started on the shaft timbering and on the enlargement of the camp already built. The camp buildings include emergency hospital, 4 bunk houses, 2 shanties, 1 cottage, general office, engineers' office and mess hall. The buildings at the shaft include mule shed, hoist room and compressor house, storage building, blower house, blacksmith shop and 2 coal sheds. Excavation was started on August 4 and the average weekly progress to the end of the year was 61.4 feet in an easterly direction and 65.2 feet westerly with a maximum for the week ending December 1, 1928, when 71.0 feet was excavated in the east section and 89.5 feet in the west. At the end of the year the excavation under this contract at Shaft 6 was 1,060.0 feet in the section east of the shaft and 1,117.0 feet in the section west, a total of 2,177.0 feet. Pumpage at the end of the year was approximately 27 gallons per minute.

The principal items of plant at Shaft 6 were as follows:

3 Air compressors, with a combined capacity of 1,623 cu. ft. per min., the largest of which has a capacity of 751 cu. ft. per min. and is run by 150 H. P. motor.
1 Blower, rated at 4,000 cu. ft. of free air per min., run by 60 H. P. motor.
1 Hoist with 100 H. P. motor.
1 10′–0″ x 3′–6″ air receiver tank.
2 Mucking machines.
6 Pumps, the largest of which has a rated capacity of 200 gals. per min. under 460-foot head, run by 25 H. P. motor.
1 50-foot timber head-frame and equipment.
Cars, machine shop equipment, drilling equipment, etc.

Shaft 7. — Work was begun at Shaft 7 during the week ending May 19 with camp construction and shaft timbering. The camp buildings include a mess hall and kitchen, 4 bunk houses, wash house, 3 cottages and emergency hospital. Buildings at the shaft include general office, engineers' office, mule shed, hoist room and compressor house, storage building, blower house, blacksmith shop and locker house.

On August 11, tunnel excavation was started. The average weekly progress at this shaft was 55.7 feet easterly and 70.1 feet westerly, with a maximum of 56.5 feet easterly and 85.5 feet westerly in the week ending October 20. At the end of the year the excavation under this contract at Shaft 7 was 908.0 feet in the section east of the shaft and 1,130.5 feet west, a total of 2,038.5 feet. To support blocky, disintegrated rock in a short section west of the shaft permanent timbering was placed for a distance of 22 feet. Pumpage at the end of the year was about 325 gallons per minute.

The principal items of plant at Shaft 7 were as follows:

3 Air compressors, with a combined capacity of 1,551 cu. ft. per min., the largest of which has a capacity of 751 cu. ft. per min. and is run by a 150 H. P. motor.
1 Hoist, driven by 100 H. P. motor.

1 10′–0″ x 3′–6″ air receiver tank.
1 Blower, rated at 4,000 cu. ft. of free air per min., run by 60 H. P. motor.
2 Mucking machines.
7 Pumps, the largest of which has a rated capacity of 450 gals. per min. under 160-foot head, driven by 30 H. P. motor.
1 50-foot head-frame and equipment.
Cars, machine shop equipment, drilling equipment, etc.

Shaft 8. (Under the supervision of the Hardwick Office of the Coldbrook-Swift Tunnel Division). — Construction at Shaft 8 was begun on May 5, 1928. The contractor erected near the shaft site a general office and emergency hospital, several bunk houses, a mess house, and buildings for housing equipment. An engineers' office was established near the shaft in a building owned by the Commission. The top of the shaft was closed in on three sides by concrete foundation walls of the future intake structure and a wooden bulkhead, sealed at the bottom by rammed and puddled earth, made the fourth side. The shaft was excavated, the preliminary lining placed, the east tunnel driven 142.5 feet and the west tunnel 135.0 feet when on November 10 the work was discontinued in order to install the cages in the shaft. Pumpage at the shaft did not exceed 10 gallons per minute until a stream of about 90 gallons per minute was encountered about 90 feet below the surface. This stream was confined to a pipe and shut off, after which the shaft pumpage decreased to 20 gallons per minute and finally 10 gallons per minute at the completion of the shaft. Pumpage again increased to about 50 gallons per minute with the start of tunnel excavation. From a spring encountered in the shaft the water supply is pumped to an elevated tank, from which the various buildings are supplied by gravity.

Miscellaneous Construction Data, Shaft 8

Total depth of shaft	253 feet
Depth of earth	3 feet
Work begun	May 5, 1928
Earth excavation begun	May 23, 1928
Rock excavation begun	June 1, 1928
Maximum depth of rock excavated in one week	25 feet
First concrete lining placed	July 8, 1928
Shaft excavation completed	Oct. 10, 1928
Tunnel excavation started	Oct. 5, 1928

The principal items of plant used in sinking Shaft 8 or delivered ready for installation as a part of the tunnel excavating plant are summarized as follows:

Equipment on Hand, in Use

2 Air compressors, each of 750 cu. ft. per min. capacity, run by 100 H. P. motors.
1 Steam hoist.
1 Stiff leg derrick.
3 Pumps, the largest of which has a rated capacity of 190 gal. per min., under 240-foot head.
Cars, drill equipment, machine shop equipment, etc.

Equipment on Hand, not in Use

1 Air compressor, capacity 750 cu. ft. per min.
1 Mine hoist.
1 Pump, capacity 300 gal. per min. under 275-foot head, run by 40 H. P. motor.
1 Concrete mixer, gasoline, ¾ cu. yd. capacity.
3 Mucking machines.

The work done and materials furnished under the principal items of Contract 17 were as follows:

	Shaft 5	Shaft 6	Shaft 7	Shaft 8
Rock excavation in shafts, and in tunnel within 50′ of shafts (cu. yds.)	–	–	–	4,664
Excavation in tunnel, except within 50′ of shafts (cu. yds.)	13,261	14,599	13,385	1,211
Shaft and tunnel drainage (lin. ft.)	1,953	2,178	2,038	522
Forms for preliminary concrete lining, Shaft 8 (lin. ft.)	–	–	–	217
Concrete masonry in shafts (cu. yds.)	9	–	–	715
Concrete masonry not in shafts or tunnel (cu. yds.)	–	–	–	300
Permanent timbering in tunnel (M ft. BM)	–	–	1.84	–
Temporary timbering in tunnel (M ft. BM)	3.44	–	–	–
Portland cement (bbls.)	12	–	–	1,283
Earth excavation (cu. yds.)	–	–	–	570
Rock excavation except in shafts or tunnel (cu. yds.)	–	–	–	760
The contractor's total force averaged (men)	73	76	72	50

Coldbrook-Swift Tunnel Division — Hardwick Office

The Coldbrook-Swift Tunnel Division has charge of the field work in connection with the proposed Coldbrook-Swift Tunnel extension to the Swift River Reservoir and of the construction at the Ware River Intake at Shaft 8 of the Wachusett-Coldbrook Tunnel included in Contract 17 and hereinbefore described. The division office was continued at Hardwick Center and a field office was established at Shaft 8 after work under Contract 17 was begun. Stream flow measurements and studies were made by the personnel of this office under the immediate supervision of engineers from the Headquarters office.

Office Work

Topographic plans were prepared for the diversion dam on the Ware River at Shaft 8 and for Shafts 9, 10, 11 and the west portal of the Coldbrook-Swift Tunnel. Real estate maps covering proposed takings for the tunnel, and of various properties in the Ware River valley upsteam from Shaft 8 were made. Cross sections of Shaft 8 were plotted and estimates prepared. Compressive tests were made on concrete test cylinders cast at the intake works at Shaft 8. These tests were made at the Worcester Polytechnic Institute.

Field Work

A precise taping of the Coldbrook-Swift Tunnel center line was made and later checked by triangulation. Precise level runs were made to supplement those made last year. Surveys were made of the real estate along the Coldbrook-Swift Tunnel line, of various water power privileges and properties upstream from the Ware River Intake, of the Village of White Valley and of the dam of the White Bros. mill pond. Rod soundings and topography were taken at the site of the Portal of the Coldbrook-Swift Tunnel, a profile for a short distance along the Ware River was taken, a proposed access road to Shaft 10 was laid out and cross sectioned, and the line of the Wachusett-Coldbrook Tunnel checked. Monuments were cast and set along the Coldbrook-Swift Tunnel line and staff gages were made and set on the ponds of the Chicopee River watershed. Stream flow measurements were made on the Ware, Swift, Quaboag, Chicopee and Connecticut rivers.

Progress of Construction

To date all construction work supervised from the Hardwick office has been on Shaft 8 of Contract 17, hereinbefore described, with the exception of installation of small gage houses at White Valley and Bircham Bend gaging stations.

Swift River Reservoir Division — Enfield Office

The Swift River Reservoir Division has charge of the field work in the Swift River Valley in connection with the proposed Swift River Reservoir.

Office Work

During the year about 9,740 acres of topography within and adjacent to the proposed reservoir were mapped on a scale of 1″=200′, this bringing the total mapped to 16,040 acres, 9,005 of which were traced on record tracings. Property as represented by 470 requests from owners of real estate for appraisal by the Commission was located and sketches showing approximate location of the same were returned to the Headquarters office. Property purchased by the Commonwealth was plotted on a general property map with a scale of 1″=1,000′.

Real estate surveys plotted during the year amounted to 30,200 acres, making the total to date 32,997 acres. These plots were made upon mounted record topographic maps at a scale of 1″=200′. Preliminary tracings covering 22,070 acres were made, and 4,700 acres were checked as final tracings. The final tracings show the ownership of the land together with metes, bounds and area, the latter of which has been subdivided into various classifications of culture.

Work on real estate titles was done as required, data pertaining to cemeteries in the reservoir area prepared and photographs taken were developed, printed and mounted as required.

Field Work

The field work consisted principally of surveys, topographic and real estate. During the year 5,393 acres of topography were taken, making the total to date 16,860 acres or 26.34 square miles, this being about two-thirds of the area required to be surveyed. Some detailed topography was taken in the vicinity of proposed structures. Photographs were taken of buildings acquired or recommended to be purchased both in the Swift River Valley and elsewhere. Photographs were also taken from time to time of the construction work in progress in other divisions. Real estate surveys during the year totalled 31,657 acres, making the total to date 35,915 acres or 56.12 square miles. Staff gages were set along the Swift River and read weekly.

To meet the forest fire hazard, a truck was purchased in March and equipped to carry a portable gasoline-driven fire pump, 2,500 feet of hose and other fire fighting apparatus. This equipment is housed in Enfield. Six of the assistant engineers of the division office were appointed deputy forest wardens in all of the towns in the Swift River Valley affected by the Commission's operations. The apparatus was called to 6 forest fires which threatened to spread over extensive areas. The damage was confined to a total of 47 acres of land. The apparatus also assisted at 6 building fires.

In preparation for the future removal of bodies, careful copies were made of inscriptions from all headstones and monuments in Pelham Hollow Cemetery, Prescott; Town House Cemetery, Prescott; Church Cemetery, Enfield; and Cemetery Hill Cemetery, Enfield. Locations of each headstone, monument and grave were made and 451 individual cemetery lots were photographed. In order to facilitate the work of removing bodies from the cemeteries, two employees of this division were licensed as undertakers by the towns of Enfield, Greenwich, Prescott and Dana. During the year, 40 bodies were moved to privately-owned lots outside of the reservoir area.

Southern Sudbury Emergency Supply — Framingham Office

The construction and incidental work on the Southern Sudbury Emergency Supply was handled from the Framingham office until February 29, 1928, when, the work being nearly completed, the office was discontinued and all records, plans, field notes and supplies were turned over to the Headquarters office.

Office Work

Record plans and cross sections of borrow pits and special excavations on Contracts 5, 6, 7, 11, 13 and 16 were plotted and checked at the Framingham office. Property calculations and location of property bounds were made. Computations for all final estimates were completed.

Field Work

Besides providing lines and grades for work under construction, a survey was made on each pipe line to secure data for record plans. All angle points, gate, blow-off and relief valves, manholes, etc., were referenced to existing landmarks. Important property lines were run out and referenced and during May and June, 1928, 160 stone bounds were set.

Progress of Contracts

Contract 5. — Contract 5 with the Lock Joint Pipe Co. of Ampere, New Jersey, for the Cordaville pipe line, a 30″ pipe from Cordaville to Sudbury Reservoir, was practically completed on December 17, 1927. The work was completed on April 6, 1928, the total value thereof being $83,762.86.

The work done and materials furnished under the principal items of the contract were as follows:

	During Year ending Nov. 30, 1928	Total
Furnishing and laying 30-in. concrete pipe	–	8,777 ft.
Furnishing and laying 18-in. cast iron pipe	–	223 ft.
Furnishing and laying 12-in. cast iron pipe	–	271 ft.
Earth excavation, fill and refill	1,012 cu. yds.	9,992 cu. yds.
Rock excavation and refill	–	367 cu. yds.

Contract 6. — Contract 6 with F. A. Mazzur Co., Inc., of Boston for the construction and equipment of the Cordaville pumping station was nearly finished at the beginning of the year. On December 13, 1927, the temperature in the house, maintained at 55° F., proved too low and chlorine ice formed in the chlorinating apparatus, crippling the operation and allowing chlorine gas to fill the building. A new thermostat with a range high enough to prevent hydration of the chlorine was installed. A satisfactory acceptance test on the main pump was made on October 18, 1928. The work was completed on May 16, 1928, the total value thereof being $17,385.04.

Contract 7. — Contract 7 with Cenedella & Co. of Milford, Mass., for the construction of a 30-inch cast iron pipe line from Hopkinton Reservoir to a connection with the Cordaville pipe line at Cordaville, was nearly completed at the beginning of the year. The work was completed on December 27, 1927, the total value thereof being $134,365.72.

The work done and materials furnished under the principal items of the contract were as follows:

	During Year ending Nov. 30, 1928	Total
Furnishing and laying 30-inch cast iron pipe	–	6,977 ft.
Excavating, fill and refill	659 cu. yds.	12,932 cu. yds.
Furnishing and placing paving	–	80 cu. yds.
Furnishing and placing riprap	–	267 cu. yds.
Furnishing and placing concrete	–	43 cu. yds.
Furnishing and placing 18-inch cast iron culvert pipe	–	120 ft.

Contract 11. — Contract 11 with Antonio Mogavero of Peabody, Mass., was for the construction of a 24-inch cast iron pipe line from Ashland Reservoir to the gate house at Framingham Reservoir No. 2. About 1,000 feet of the grading was left to be cleaned up in the spring of 1928. A cork and pitch frost-proofing was applied to the air relief access wells and underground Venturi meter recorder chamber. The work was practically completed early in the year, and was completed on September 24, 1928, the total value thereof being $130,145.35.

The work done and materials furnished under the principal items of the contract were as follows:

	During Year ending Nov. 30, 1928	Total
Furnishing and laying 24-inch cast iron pipe	–	13,426 ft.
Furnishing and laying 20-inch cast iron pipe	–	937 ft.
Earth excavation, fill and refill	2,102 cu. yds.	13,102 cu. yds.
Rock excavation and refill	–	616 cu. yds.
Furnishing and placing riprap	–	38 cu. yds.
Furnishing and placing paving	40 cu. yds.	40 cu. yds.
Furnishing and placing concrete	15 cu. yds.	85 cu. yds.

Contract 13. — Contract 13 with the Portland Contracting Company of Portland, Maine, for the construction of a 20-inch cast iron pipe line from Whitehall Reservoir to and including the diversion dam on City Brook near City Road in the Town of Hopkinton, which was nearly completed at the beginning of the year, was completed on June 12, 1928, the total value thereof being $60,603.17.

The work done and materials furnished under the principal items of the contract were as follows:

	During Year ending Nov. 30, 1928	Total
Furnishing and laying 20-inch cast iron pipe	400 ft.	6,750 ft.
Excavation, fill and refill	2,102 cu. yds.	6,702 cu. yds.
Excavation at diversion dam	–	464 cu. yds.
Furnishing and placing impervious core and blanket at diversion dam	9 cu. yds.	739 cu. yds.
Furnishing and placing pervious embankment	–	1,589 cu. yds.
Furnishing and placing soil dressing	–	158 cu. yds.
Furnishing and placing concrete	14 cu. yds.	64 cu. yds.
Furnishing and placing paving	41 cu. yds.	66 cu. yds.

Contract 15. — Since June 1 the Metropolitan District Commission has assumed the payments to the Marlborough Electric Company under Contract 15 for fur-

nishing electricity at the Cordaville pumping station on the line from Hopkinton Reservoir to Sudbury Reservoir. Monthly payments up to that time totalled $270.09.

Contract 16. — Contract 16 with the Sanders Engineering Company of Portland, Maine, for an open channel from the reservoir formed by the dam built under Contract 13 to the Hopkinton Reservoir, was nearly completed at the beginning of the year. The work was completed on July 9, 1928, the total value thereof being $32,695.16.

The work done and materials furnished under the principal items of the contract were as follows:

	During Year ending Nov. 30, 1928		Total	
Clearing	1.4	acres	26.6	acres
Grubbing	0.3	acre	7.3	acres
Excavation	4,352	cu. yds.	17,852	cu. yds.
Gravel fill	254	cu. yds.	254	cu. yds.
Furnishing and placing concrete	1	cu. yd.	32	cu. yds.

Geological Data

Chapter 321, Acts of 1927, provides that the Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the state. Such information was published in the annual report for the year ending November 30, 1927, since which time tunnel excavation from six shafts located in the towns of Holden and Rutland on the Wachusett-Coldbrook Tunnel has been prosecuted to an aggregate length of about 18,000 feet. Shaft 1 at the east end of this tunnel in the Town of West Boylston has been sunk to a depth of 159 feet, 129 feet of which is in rock, and Shaft 8 at the Ware River intake in the Town of Barre has been completed, the total depth being about 253 feet, practically all of which is in rock. No further geologic data is as yet available in the valley of the Swift River or at the Beaver Brook dike of the Swift River Reservoir. Borings were completed on the tunnel extension from Shaft 8 to the Swift River Reservoir in December, 1927.

Surface and rock profiles developed from these borings along the Wachusett-Coldbrook and the proposed Coldbrook-Swift tunnels reveal the following data as to probable cover above the tunnel, not including that portion in the vicinity of the portal:

Maximum Overall Cover. — Approximately 820 feet, all rock, located between Shafts 4 and 5 in the Town of Rutland.

Minimum Overall Cover. — Approximately 115 feet (includes 67 feet± of rock and 48 feet± of unconsolidated drift); located between Shaft 11 in Muddy Brook Valley in the Town of Hardwick, and the portal in the Town of Greenwich.

Lowest Rock. — Elevation 373; located at Shaft 1 in the Town of West Boylston.

Highest Rock. — Elevation 1,220 feet±; located between Shafts 4 and 5 in the Town of Rutland.

Deepest drift cover penetrated by diamond drill borings — 135 feet located between Shaft 11 and the portal.

Structure and Distribution of the Formations

Of the rocks exposed in borings and excavations to date, there is a great variety in quality and appearance because of original differences in composition. A further variety is occasioned by the fact that some of these works are mixed with a granite, making thereby products quite unlike either one of the originals. All of the non-igneous rocks are metamorphosed, some of them extremely so, and in the areas of the highly injected schists and gneisses, it is somewhat difficult to determine whether the rock was originally sedimentary or igneous.

From information obtained to date, the Wachusett-Coldbrook Tunnel is being or may be expected to be excavated through the following rock formations:

1. A fine grained but distinctly granular phyllitic quartzite which is plainly foliated, occurring rather extensively in the east portion of the tunnel. This rock grades from a quartz-mica phyllite to a quartzite by the increase of quartz and

decrease of mica, and in addition to the high percentage of quartz, there are also present considerable quantities of carbonate, which seem to permeate the quartzose groundmass. This rock, as it occurs in Shaft 1, is divided by numerous cross-fractures, some of which are completely sealed with calcite veining.

2. A light colored biotite-muscovite granite, grading between an almost pure feldspar-quartz rock without mica and one with large amounts of black and brown mica. Extensive pegmatitic facies are also present. This rock has previously, in the preliminary geological map of Massachusetts, been given the name of Fitchburg Granite, and has been mapped as occurring along the east half of the tunnel. There is also, however, a granite occurring in the western part of the tunnel area, and this has also been classified tentatively as belonging to the Fitchburg Granite, as studies made to date do not warrant a new name. There is not much difference in character or quality, and the behavior in other respects, such as its mixing and injection relations to the overlying schists is about the same.

The granite, as found in the eastern section of the tunnel area, is composed chiefly of quartz, abundant microcline and orthoclase, albite and other accessory minerals such as magnetite, apatite, and titanite. It is essentially fresh and shows only slight alteration. Where it has come into proximity to the schists, there is a considerable increase in mica. The granites so far studied as found in the western section of the tunnel area, show only small changes in the mineral content, there being practically no change in the essential primary minerals, but a few additional secondary minerals including leucoxene and epidote. In some cases they take on a marked foliated or gneissic structure.

3. A medium grained quartz-mica schist, which appears to be the most extensively developed single type. In some places it is very quartzose becoming essentially a quartzite or quartzitic schist. It is commonly very micaceous and schistose. In its simplest and finest grain, it somewhat resembles the phyllitic quartzite mentioned above. Some variations in its character are shown by the addition of feldspars, with considerable amounts of calcite and zircon, the latter being prominent by the halos surrounding most of the grains. This rock has previously, in the preliminary geological map of Massachusetts, been given the name of Paxton Quartz Schist.

4. A strongly and finely foliated mica schist showing generally a very strong structure. Some occurrences are wholly micaceous, and indicate metamorphism from a carbonaceous shale. The whole is considerably injected with granite and pegmatite, which produces some variations in the rock, especially in increasing the garnet content and introducing feldspathic substances, thus making it a little abnormal from the type.

5. The first three types seldom occur in a simple condition but are generally mixed, making the rock in part quartzitic or phyllitic, as the case may be, and in part granite. Portions of it are coarse grained pegmatite, which gives to the rock a gneissic effect, and other portions are quartz-mica or mica-schist. The resultant mixed rock is so prominent and widespread that it has been given a tentative formational name of Paxton Mixed Injection Schist. It therefor includes a great variety, varying from simple schists on one side with small amounts of injected igneous material to gneissoid granites on the other with included, partly digested, and redistributed material from the original overlying schists. In the vicinity of Shaft 8, these rocks are predominantly of igneous origin, with foliated structure; and in some cases show an augen structure with feldspar phenocrysts.

Due to the great lengths of tunnel to be excavated between the headings at the shafts, and also to the scarcity of surface outcrops along the line, it is impossible at this time to set any exact limits to these formations. Beginning at the east end and going westward there is probably the following sequence of formations. The phyllitic quartzite extends from east of Shaft 1 to approximately 3,000 feet west, where it appears to dip at a small angle (25°) into the Fitchburg Granite. The Fitchburg Granite comes next and apparently continues for most of the distance to Shaft 3. The general structure can be observed in the included highly quartzose and feldspathic schist rocks, and is seen to be very flat, there being only slight variations in the dip from the horizontal. The structure, as plotted from measurements taken close together, shows a slight wavy or rolling schistosity, but when all

the small variations are averaged, the resultant structure is near the horizontal. Throughout the excavation, at this time, the percentage of included schist is considerable. The intrusive relation of the granite to the schist is clear. The next section of tunnel to somewhere between Shafts 3 and 4 is chiefly mica schist with numerous granite and pegmatitic bodies. The short section of tunnel excavated at Shaft 3 shows the poorest quality of rock of any of the formations. It has been extremely crushed and folded and has a dominant fracture cleavage, but some specimens taken from between these surfaces show minute crenulated folds. The schist, in this short section of tunnel, is considerably intruded with the Fitchburg Granite and pegmatite, and because of the end-stage and subsequent alteration to the latter a rather soft and considerably disintegrated rock has resulted, requiring four short lengths of timbering to be placed. The granite intrusives are confined to large cross cutting veins, some of dike proportions, whereas the pegmatite seems to have permeated the schist and its effects can be seen at remote distances from the main body. The distance between Shafts 4 and 6 is taken up by almost straight Paxton Quartz Schist, with some variations to the more quartzitic type together with some lenses of more shaley rock. The structure between these points, as interpolated from tunnel excavations, and a few surface outcrops, is horizontal or nearly so. A very striking example is found at Shaft 5, in the middle of this belt, where for a depth of 650 feet in the shaft and approximately 3,300 feet in the tunnel, the dip does not vary more than 10 to 15 degrees from the horizontal. The rock, throughout this section, is distinctly bedded, and is intruded by pegmatite, chiefly consisting of orthoclase. These intrusions are found in the form of large isolated augens with stringer veins, and appear to cut across the bedding, indicating a fusion and replacement of the schist, rather than dynamic injection. Very close to Shaft 6 the Paxton Quartz Schist merges into a mixed schist and granite rock, called here the Paxton Mixed Injection Schist. The contact is not clearly defined, but seems to extend over an area as the former loses its idenity as such gradually with increases of the mixed schist rock. Minor faulting in the quartz schist indicates a fault contact, now obscured by granitic injections. The Paxton Mixed Injection Schist extends from Shaft 6 to Shaft 8, with intervening bodies, uncertain in extent, of granite of the Fitchburg type. At Shaft 7 the intrusive relation of the granite to the schist is very clear, as in a great many sections it results in a marked banded or ribbon gneiss effect, which has resulted from the granite replacing the schist only in part. The prevailing dip at this point is about 30° east, and at Shaft 8 it is about 40° west. The ribbon gneiss effect is not so apparent at this latter point.

The tunnel excavations to date, taken as a whole, are comparatively dry, and no one formation can be pointed out as being a large water bearer. The Paxton Quartz Schist is the dryest formation, whereas the Fitchburg Granite and Paxton Mixed Injection Schist, are letting water into the tunnel at greater rates. The water, at these points of leakage, is coming in mainly along joints, and crush zones. The mica schist at Shaft 3, due to its broken and disintegrated condition, allows water to enter from a great many small fractures, rather than from any particular set of joints.

List of Drawings and Tables

For General Plan of Metropolitan Water Supply and Profile of Wachusett-Coldbrook Tunnel, see Second Annual Report.

The following tabulations are appended to this report:

Monthly Progress — Real Estate Negotiations for the Swift River Reservoir.
Location of Real Estate Acquired for the Swift River Reservoir.
Real Estate Takings.
Status of Contracts in Force between Nov. 30, 1927, and Nov. 30, 1928.
Total Value of Work Accomplished under Contracts in Progress During Year Ending November 30, 1928.
Canvass of Bids, Contracts 14 and 17.

Respectfully submitted,

FRANK E. WINSOR,
Chief Engineer.

24 School Street, Boston, Mass.
January 2, 1929.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
Administration (Commissioners' Office):		
Salaries, Commissioners	$10,500.00	$24,612.80
Salaries, Clerical	10,210.00	17,729.03
General Legal Expense	962.82	1,377.30
Furniture and Fixtures	−422.37	1,814.78
Rent and Upkeep	2,961.71 [1]	2,961.71
Automobile Purchase	809.00 [4]	809.00
Automobile Maintenance	418.71	668.48
Miscellaneous Expense (undistributed)	601.22	4,732.80
Advertising	748.65	748.65 [2]
Printing and Blueprinting	1,121.85	1,121.85 [2]
Stationery and Office Supplies	289.95	289.95 [2]
Postage	133.69	133.69 [2]
Total Administration	$28,335.23	$57,000.04
Engineering, Headquarters Office:		
Salaries, Engineering	$78,630.29	$146,435.10
Salaries, Clerical	8,717.90	17,315.80
General Consultant Expense	17,417.08	26,497.52
Furniture and Fixtures	1,999.73	10,407.82
Laboratory Equipment	1,425.48	1,425.48
Laboratory Supplies	1,369.50	1,369.50
Rental of Equipment	865.00	865.00
Engineering Instruments	40.62	40.62
Rent and Upkeep of Boston Office	9,739.47	21,579.62
Rent and Upkeep of Springfield Laboratory	576.88	576.88
Automobile Purchase	1,495.70 [4]	1,495.70
Automobile Maintenance	550.00	807.30
Special Experiments	2,304.63	2,304.63
Miscellaneous Expense (undistributed)	3,279.07	8,289.28
Printing and Blueprinting	2,387.71	2,387.71 [2]
Stationery and Office Supplies	907.29	907.29 [2]
Postage	205.07	205.07 [2]
Total Engineering, Headquarters Office	$131,911.42	$242,910.32
Unassigned:		
Unassigned Supplies and Equipment	−$505.17	$1,068.81
Total Unassigned	−$505.17	$1,068.81
Total General Overhead	$159,741.48	$300,979.17

Distribution of General Overhead

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
Administration:		
Wachusett-Coldbrook Tunnel Division	$9,784.48	$20,760.21
Coldbrook-Swift Tunnel Division	2,020.15	3,369.52
Swift River Reservoir Division	15,207.76	24,225.18
Southern Sudbury Emergency Supply	1,322.84	8,645.13
Total Administration	$28,335.23	$57,000.04
Engineering, Headquarters Office:		
Wachusett-Coldbrook Tunnel Division	$42,565.56	$85,945.86
Coldbrook-Swift Tunnel Division	7,693.27	12,336.56
Swift River Reservoir Division	76,812.49	111,630.48
Southern Sudbury Emergency Supply	4,840.10	32,997.42
Total Engineering, Headquarters Office	$131,911.42	$242,910.32

Wachusett-Coldbrook Tunnel Division

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
General Overhead:		
Administration	$9,784.48	$20,760.21
Engineering	42,565.56	85,945.86
Total General Overhead	$52,350.04	$106,706.07
Engineering:		
Salaries, Engineering and Clerical	$65,785.81	$112,858.75
Consultant Expense	1,082.41	1,628.06
Furniture and Fixtures	−8,614.01	1,070.63
Engineering Instruments	7,141.00 [3]	7,141.00
Rent and Upkeep	1,993.08	3,927.64
Automobile Purchase	4,514.96 [4]	4,514.96
Automobile Maintenance	2,851.51	5,105.99
Contracts for Investigations and Surveys	16,075.11 [5]	16,075.11
Miscellaneous Expense (undistributed)	−16,069.14	2,987.52
Advertising	4.22 [1]	4.22
Printing and Blueprinting	392.01 [1]	392.01
Stationery and Office Supplies	1,338.90 [1]	1,338.90
Postage	175.35 [1]	175.35
Total Engineering	$76,671.21	$157,220.14
Real Estate (General Construction):		
Legal and Expert Expense	$1,468.41	$3,512.46
Consultant Expense	394.40	394.40
Labor	1,016.55	1,016.55
Miscellaneous Expense	16.24	241.24
Purchases and Settlements	79,822.46	96,382.46
Taxes	652.78	757.12
Police Protection, Labor	10.00	10.00
Special Agents, Salaries	1,083.00	1,083.00
Furniture and Fixtures	117.67	117.67
Automobile Purchase	595.50	595.50
Automobile Maintenance	121.69	121.69
Miscellaneous Expense (undistributed)	76.35	76.35
Printing	7.89	7.89
Total Real Estate	$85,382.94	$104,316.33

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
WARE WATERSHED PROTECTION:		
Legal and Expert Expense	$2,276.10	$2,724.43
Consultant Expense	197.30	763.70
Labor	795.00	1,265.00
Miscellaneous Expense	23.63	45.84
Purchases and Settlements	71,205.48	294,488.66
Taxes	0.00	4,960.92[6]
Total Ware Watershed Protection	$74,497.51	$304,248.55
WARE SUPPLY DAMAGES:		
Consultant Expense	−$591.70	$0.00
Total Ware Supply Damages	−$591.70	$0.00
WARE DIVERSION DAMAGES:		
Consultant Expense	$0.00	$452.39
Contracts for Investigations and Surveys	63.27	63.27
Miscellaneous Expense (undistributed)	330.03	1,595.03
Printing and Blueprinting	24.99	24.99
Total Ware Diversion Damages	$418.29	$2,135.68
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 4, Sinking Shaft 5 and driving 1,367 linear feet of tunnel	$198,158.83	$290,581.99
Contract No. 8, Sinking Shafts 6 and 7 and driving 3,062.2 linear feet of tunnel	335,617.53	456,784.26
Contract No. 10, Construction and maintenance of Transmission Line	7,158.50	95,765.09
Contract No. 12, Sinking Shafts 2, 3 and 4 and driving 3,809.6 linear feet of tunnel	451,564.28	632,727.44
Contract No. 14, Construction of East Portion of Wachusett-Coldbrook Tunnel and Shaft 1	241,650.13	241,650.13
Contract No. 17, Construction of West Portion of Wachusett-Coldbrook Tunnel and Shaft 8	442,443.28	442,443.28
Total Contracts	$1,676,592.55	$2,159,952.19
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$91.88[1]	$91.88
Temporary Equipment	4,750.10	4,750.10
Miscellaneous Expense	446.58	888.02
Investigations and Surveys	898.34	898.34
Total	$6,186.90	$6,628.34
Total Wachusett-Coldbrook Tunnel Division	$1,971,507.74	$2,841,207.30

COLDBROOK-SWIFT TUNNEL DIVISION

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
GENERAL OVERHEAD:		
Administration	$2,020.15	$3,369.52
Engineering	7,693.27	12,336.56
Total General Overhead	$9,713.42	$15,706.08

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
ENGINEERING:		
Salaries, Engineering and Clerical	$20,636.19	$28,297.69
Furniture and Fixtures	−3,570.88	225.49
Engineering Instruments	3,284.77 [3]	3,284.77
Rent and Upkeep	1,649.46	1,738.86
Automobile Purchase	1,980.00 [4]	1,980.00
Automobile Maintenance	1,752.00	2,363.15
Contracts for Investigations and Surveys	12,831.65 [5]	12,831.65
Materials of Construction	2.25	2.25
Miscellaneous Expense (undistributed)	−6,883.35	1,847.73
Printing and Blueprinting	113.09 [1]	113.09
Stationery and Office Supplies	595.66 [1]	595.66
Postage	93.93 [1]	93.93
Total Engineering	$32,484.77	$53,374.27
REAL ESTATE:		
Legal and Expert Expense	$220.98	$413.82
Miscellaneous Expense	4.80	12.30
Purchases and Settlements	236.30	236.30
Taxes	867.47	867.47
Fire Protection, Equipment	17.06	17.06
Total Real Estate	$1,346.61	$1,546.95
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$91.87 [1]	$91.87
Miscellaneous Expense	−91.87	0.00
Total	$0.00	$91.87
Total Coldbrook-Swift Tunnel Division	$43,544.80	$70,719.17

SWIFT RIVER RESERVOIR DIVISION

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
GENERAL OVERHEAD:		
Administration	$15,207.76	$24,225.18
Engineering	76,812.49	111,630.48
Total General Overhead	$92,020.25	$135,855.66
ENGINEERING:		
Salaries, Engineering and Clerical	$74,472.02	$128,482.07
Furniture and Fixtures	−6,916.51	1,167.17
Engineering Instruments	5,395.91 [3]	5,395.91
Rent and Upkeep	378.53	609.17
Automobile Purchase	6,056.96 [4]	6,056.96
Automobile Maintenance	3,166.34	5,171.48
Contracts for Investigations and Surveys	35,448.91 [5]	35,448.91
Office Buildings	923.23	923.23
Miscellaneous Expense (undistributed)	−36,775.40	2,149.74
Printing and Blueprinting	526.04 [1]	526.04
Stationery and Office Supplies	2,373.37 [1]	2,373.37
Postage	203.36 [1]	203.36
Total Engineering	$85,252.76	$188,507.41
REAL ESTATE:		
Legal and Expert Expense	$26,695.31	$54,693.61
Labor	56.10	56.10

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
REAL ESTATE — *Concluded.*		
Miscellaneous Expense (undistributed)	$222.10	$763.25
Advertising	19.29	19.29
Stationery and Office Supplies	0.45	0.45
Purchases and Settlements	1,142,218.90	2,103,020.98
Taxes	9,984.20	14,351.51
Fire Protection, Equipment	1,817.43	1,817.43
Automobile Purchase	200.00	200.00
Automobile Maintenance	36.61	36.61
Miscellaneous Expense	14.36	14.36
Special Agents, Salaries	1,431.33	1,431.33
Equipment	118.33	118.33
Automobile Purchase	609.96	609.96
Automobile Maintenance	274.28	274.28
Miscellaneous Expense (undistributed)	165.91	165.91
Printing	41.60	41.60
Postage	1.42	1.42
Renting Agents, Salaries	2,155.43	2,155.43
Furniture and Fixtures	29.29	29.29
Miscellaneous Expense	14.04	14.04
Total Real Estate	$1,186,106.34	$2,179,815.18
SWIFT RESERVOIR DAMAGES:		
Consultant Expense	$0.00	$921.47
Total Swift Reservoir Damages	$0.00	$921.47
SWIFT DIVERSION DAMAGES:		
Salaries	$3,011.86	$3,011.86
Consultant Expense	0.00	1,360.54
Automobile Maintenance	1.25	1.25
Contracts for Investigations and Surveys	569.47	569.47
Miscellaneous Expense	696.25	2,065.46
Total Swift Diversion Damages	$4,278.83	$7,008.58
CEMETERIES:		
Labor	$545.00	$545.00
Materials	339.43	339.43
Purchases and Settlements	556.00	556.00
Transportation of Bodies	45.00	45.00
Transportation of Monuments	133.00	133.00
Miscellaneous Expense	51.81	51.81
Total Cemeteries	$1,670.24	$1,670.24
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$214.78 [1]	$214.78
Miscellaneous Expense	−214.78	0.00
Total	$0.00	$214.78
Total Swift River Reservoir Division	$1,369,328.42	$2,513,993.32

SOUTHERN SUDBURY EMERGENCY SUPPLY

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
GENERAL OVERHEAD:		
Administration	$1,322.84	$8,645.13
Engineering	4,840.10	32,997.42
Total General Overhead	$6,162.94	$41,642.55

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
ENGINEERING:		
Salaries	$6,889.83	$33,222.97
Consultant Expense	0.00	3,816.25
Furniture and Fixtures	−4,909.91	30.70
Engineering Instruments	216.06 [3]	216.06
Rent and Upkeep	118.22	543.40
Automobile Purchase	1,919.00 [4]	1,919.00
Automobile Maintenance	536.24	1,514.45
Labor	0.00	173.00
Miscellaneous Expense (undistributed)	−564.52	1,298.52
Printing and Blueprinting	215.33 [1]	215.33
Stationery and Office Supplies	567.87 [1]	567.87
Postage	52.80 [1]	52.80
Total Engineering	$5,040.92	$43,570.35
REAL ESTATE:		
Legal and Expert Expense	$277.27	$1,453.87
Consultant Expense	86.87	116.87
Purchases and Settlements	6,625.00	13,663.22
Total Real Estate	$6,989.14	$15,233.96
SOUTHERN SUDBURY DIVERSION DAMAGES:		
Consultant Expense	$205.73	$1,075.23
Settlements	0.00	24,000.00
Total Southern Sudbury Diversion Damages	$205.73	$25,075.23
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 5, Cordaville Pipe Line	$9,081.13	$83,262.86
Contract No. 6, Cordaville Pumping Station	3,399.81	17,385.04
Contract No. 7, Hopkinton Pipe Line	21,529.62	134,365.72
Contract No. 11, Ashland Pipe Line	20,102.49	130,145.35
Contract No. 13, Whitehall Pipe Line	17,472.71	60,603.17
Contract No. 16, Whitehall Open Channel	26,456.09	32,695.16
Total Contracts	$98,041.85	$458,457.30
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$7,960.11 [1]	$7,960.11
Miscellaneous Expense	−5,768.08	2,749.08
Labor	1,011.00	1,011.00
Materials of Construction	207.09	207.09
Total	$3,410.12	$11,927.28
Total Southern Sudbury Emergency Supply	$119,850.70	$595,906.67
SUMMARY		
Wachusett-Coldbrook Tunnel Division	$1,971,507.74	$2,841,207.30
Coldbrook-Swift Tunnel Division	43,544.80	70,719.17
Swift River Reservoir Division	1,369,328.42	2,513,993.32
Southern Sudbury Emergency Supply	119,850.70	595,906.67
Unassigned	−505.17	1,068.81
Grand Total	$3,503,726.49	$6,022,895.27

Receipts from Rents, Sales, etc.

	Year ending Nov. 30, 1928	Total to Nov. 30, 1928
Receipts from Sales	$7,004.17	$7,515.67
Receipts from Rents	17,339.60	19,844.01
Miscellaneous Receipts	31.29	51.48
Total Receipts	$24,375.06	$27,411.16

[1] Includes expenditures prior to November 30, 1927, previously carried in other accounts.
[2] Expenditures prior to November 30, 1927, included in the Miscellaneous Expense account.
[3] Includes Engineering Instruments prior to November 30, 1927, which had been carried in the Furniture and Equipment account.
[4] Includes Automobile Purchase prior to November 30, 1927, which had been listed under Furniture and Equipment.
[5] Includes Contracts for Investigations and Surveys prior to November 30, 1927, which had been carried in the Miscellaneous Expense account.
[6] Part of purchase price.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

MONTHLY PROGRESS — REAL ESTATE NEGOTIATIONS FOR SWIFT RIVER RESERVOIR

DATE	OWNERS' OFFERS TO SELL TO COMMONWEALTH			TITLE VESTED IN COMMONWEALTH (Acres)	
	NUMBER OF OFFERS	TOTAL AREA (Acres)	AREA NOT REQUIRED (Acres)		
1927 December	31	793	9	957	
1928 January	25	1386	140	813	
February	25	1327	0	1482	
March	30	1053	0	1725	
April	21	769	103	925	
May	37	1083	75	1607	
June	55	1656	115	733	
July	41	1598	251	1009	
August	48	1302	1071	885	
September	52	1837	336	882	
October	61	1696	74	1141	
November	44	3417	843	548	
Total for Year ending Nov. 30, 1928.	470	17,917	3017	12,707	
Total to Nov. 30, 1927.	740	32,202	2468	10,890	
Total to Nov. 30, 1928.	1210	50,119	5485	23,597	

Options Outstanding Nov. 30, 1928 — 3357 Acres.
Acreage is based upon estimates obtained from deeds or other information and not from surveys.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE SWIFT RIVER RESERVOIR

TOWNS	TITLE VESTED IN COMMONWEALTH (Acres)
Belchertown	1095
Dana	2189
Enfield	5000
Greenwich	4685
Hardwick	556
New Salem	2453
Pelham	1149
Petersham	352
Prescott	5730
Shutesbury	133
Ware	254
Wendell	1
Total Dec. 1, 1928	23,597

Acreage is based upon estimates obtained from deeds or other information and not from surveys.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
REAL ESTATE TAKINGS

TAKING FOR		TAKING NO.	LOCATION	PLAN NO.	DATE OF TAKING	TITLE VESTED IN COMMONWEALTH FEE (Acres)	EASEMENT (Acres)
Wachusett - Coldbrook Tunnel		1	Holden	T-1 to T-5 incl.	July 22, 1927	186.01	3.91
			Rutland			1.86	
Wachusett - Coldbrook Tunnel		2	Rutland	T-6 to T-12 incl.	Aug. 26, 1927	90.90	8.92
			Oakham			6.62	2.00
Wachusett - Coldbrook Tunnel		3	Oakham	T-13	Nov. 11, 1927	103.58	
			Barre			181.25	0.84
Wachusett - Coldbrook Tunnel		4	West Boylston	T-1A	Aug. 21, 1928		2.57
			Holden				2.13
						570.22	20.37
*Ashland Pipe Line	Southern Sudbury Emergency Supply	1	Southborough	C-1 & C-2	July 8, 1928		0.85
			Ashland				4.48
Ashland Pipe Line		2	Ashland	C-8 to C-11 incl.	Nov. 11, 1927		9.13
			Framingham				1.34
Cordaville Pipe Line		3	Southborough	C-3 to C-7 incl.	July 8, 1928	1.14	8.75
Hopkinton Pipe Line		4	Hopkinton	C-12 to C-14 incl.	Oct. 14, 1928	64.17	4.47
						65.31	29.02
Indian Brook		5	Ashland & Hopkinton	No Plan	Sept. 2, 1927	Water Diversion	
Cold Spring Brook		6	Ashland	No Plan	Jan. 6, 1928		
Sudbury River		7	Southborough, Hopkinton, & Westborough	No Plan	Jan. 6, 1928		
City Brook		8	Hopkinton	No Plan	Jan. 6, 1928		

*Recorded in both Worcester and Middlesex Counties. All others in Worcester County.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS IN FORCE BETWEEN NOV. 30, 1927 & NOV. 30, 1928.

CONT. NO.	DESCRIPTION	LOCATION	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	BASIS OF AWARD	PAYMENTS TO DATE	FINAL ESTIMATE	DATE OF FINAL EST.
4	Shaft 5	Rutland	James J. Coughlan & Sons, Inc.	Mar. 25, 1927	Mar. 28, 1927	$ 137,854.80	$	$ * 290,581.99	June 12, '28
5	Cordaville Pipe Line	Cordaville to Sudbury Res.	Lock Joint Pipe Co.	Apr. 15, 1927	Apr. 15, 1927	78,818.00	83,262.86	83,762.86	Apr. 6, '28
6	Cordaville Pumping Sta.	Cordaville	F. A. Mazzur Co., Inc.	Apr. 29, 1927	May 2, 1927	16,357.00		17,385.04	May 16, '28
7	Hopkinton Pipe Line	Hopkinton Res. to Cordaville	Cenedella & Co.	Apr. 29, 1927	May 4, 1927	126,550.00		134,365.72	Dec. 27, '27
8	Shafts 6 & 7	Rutland	James J. Coughlan & Sons, Inc.	May 20, 1927	May 24, 1927	162,125.00		* 456,784.26	June 12, '28
9	Aerial Photographs	Chicopee and Ware Rivers	Fairchild Aerial Surveys, Inc.		Mar. 30, 1927	Additional Material 590.00		60.00	Feb. 17, '28
10	Transmission Line for Const. of Wachusett Coldbrook Tunnel	Tunnel Line	New England Power Co.		Apr. 27, 1927	Maintenance at cost	9,325.51		
11	Ashland Pipe Line	Ashland Res. to Reservoir No. 2	Antonio Mogavero	June 3, 1927	June 3, 1927	125,150.00		130,145.35	Sept. 24, '28
12	Shafts 2, 3 & 4	Holden and Rutland	Dravo Contracting Co.	May 20, 1927	May 24, 1927	259,800.00		* 632,727.44	June 12, '28
13	Whitehall Pipe Line	Whitehall Res. to City Road	Portland Contracting Co., Inc.	July 15, 1927	July 15, 1927	54,963.00		60,603.17	June 12, '28
14	East Portion Wach.-Cold. Tun.	W. Boylston, Holden, Rutland	West Construction Co. Assignee	Nov. 18, 1927	Apr. 30, 1928	4,074,981.25	241,650.13		
15	Electric Power	Cordaville Pumping Sta.	Marlborough Electric Co.		Aug. 4, 1927		270.09		
16	Whitehall Open Channel	City Road to Hopkinton Res.	Sanders Engineering Co.	Sept. 23, 1927	Sept. 23, 1927	36,720.00		32,695.16	July 9, '28
17	West Portion Wach.-Cold. Tun.	Rutland, Oakham, Barre	West Construction Co. Assignee	Nov. 18, 1927	Apr. 30, 1928	4,799,362.50	442,443.28		

* Includes construction beyond that contemplated when proposal was accepted.

COMMONWEALTH OF MASSACHUSETTS
METR DISTR WATER SUPPLY COMMISSION

TOTAL VALUE OF WORK ACCOMPLISHED UNDER CONTRACTS IN PROGRESS DURING YEAR ENDING NOV. 30, 1928

CONTRACT NUMBER	1	4	5	6	7	8	9	10	11	12	13	14	15	16	17
CONTRACTOR	PENNSYLVANIA DRILLING CO.	J.J. COUGHLAN & SONS, INC.	LOCKJOINT PIPE CO.	F.A. MAZZUR CO., INC.	CENEDELLA & CO.	J.J. COUGHLAN & SONS, INC.	FAIRCHILD AERIAL SURVEYS, INC.	NEW ENGLAND POWER CO.	ANTONIO MOGAVERO.	DRAVO CONT. CO.	PORTLAND CONT CO., INC	WEST CONST CO. (ASSIGNEE)	MARLBOROUGH ELECTRIC CO.	SANDERS ENG. CO.	WEST CONST. CO. (ASSIGNEE)
BASIS OF AWARD	SUPPLEMENTARY AGREEMENT	137,854.80	78,818.00	16,357.00	126,550.00	162,125.00	MATERIAL ONLY 590.00	OPERATION AND MAINTENANCE	125,150.00	259,800.00	54,963.00	* 4,074,981.25		36,720.00	** 4,799,362.50
DECEMBER 1927	12,831.65	127,407.80	82,424.15	16,193 43	134,365.72	176,113.90	52.50	3,235.42	126,435.09	254,071.65	54,270.51		22.57	27,095.60	
JANUARY 1928		144,531.40	82,424 15	17,172 67		218,405.30	52.50	4,167.21	129,475.23	288,073.82	60,369.38		39.86	31,731.60	
FEBRUARY		176,850.40	82,424.15	17,172.67		277,908.50	60.00	4,880.03	129,475.23	344,789.63	60,369.38		104.65	32,497.40	
MARCH		206,600.80	82,424.15	17,172.67		333,542.35		5,494.27	129,475.23	413,835.48	60,369.38		166.82	32,497.40	
APRIL		247,608.10	83,762 86	17,172 67		400,888.15		6,287.74	129,475.23	502,613.78	60,369.38		211.85	32,497.40	
MAY		264,939.10		17,385.04		432,298.60		7,004.33	129,475.23	581,371.59	60,369.38		251.49	32,497.40	4,994.00
JUNE		*** 290,581.99				*** 456,784.26		7,639.90	129,475.23	*** 632,727.44	60,603.17	6,832.45	270.09	32,497.40	17,986.20
JULY								8,352.11	129,475.23			6,832.45		32,695.16	17,986.20
AUGUST								9,007.58	129,475.23			34,633.35			36,731.54
SEPTEMBER								9,662.33	130,145.35			73,332.32			253,512.64
OCTOBER								10,361.68				152,425.85			334,996.64
NOVEMBER 1928								11,066.73				268,500.15			491,603.64

Total to first of previous month.

Total to end of previous month.

* Portion of work completed under contract 12 before contract 14 was executed reduces this amount by about 7%
** Portion of work completed under contracts 4 and 8 before contract 17 was executed reduces this amount by about 7%
*** Includes construction beyond that contemplated when proposal was accepted.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

TABULATION OF BIDS FOR CONTRACT 14 FOR THE CONSTRUCTION OF WACHUSETT – COLDBROOK TUNNEL

ITEM	DESCRIPTION	UNIT	QUANTITIES A	B	C
1	Earth excavation for Shaft 1	CU YD	1000	1000	
2	Rock excav. in shafts and tunnel within 50 ft of shaft center lines	"	9400	3400	6000
3	Excav. in tunnel except within 50 ft of shaft center lines	" "	530000	240000	290000
4	Enlargement of shafts and tunnel in rock	" "	1000	500	500
5	Shaft and tunnel drainage	LIN FT	74000	33700	40300
6	Forms for preliminary concrete lining in Shaft 1	" "	215	215	
7	" " " " " " 8	" "	250		250
8	" " concrete linings of Shafts 2, 3, 4, 5, 6 and 7	" "	75	25	50
9	Forms for concrete lining in tunnel	"	74000	33750	40250
10	Concrete masonry in shafts	CU YD	4000	2300	1700
11	" " tunnel	" "	170000	77000	93000
12	" " not included in Items 10 or 11	" "	3500	3000	500
13	Excess concrete masonry in shafts and tunnel	" "	1000	500	500
14	Permanent timbering in tunnel	M F B M	1250	500	750
15	Temporary " "	"	100	50	50
16	Dry packing	CU YD	7500	3000	4500
17	Drilling holes in rock or masonry	LIN FT	2000	1000	1000
18	Steel pipe for grouting etc	" "	10000	5000	5000
19	Connections for grouting	CONN	1000	500	500
20	Sand for grout	TON	1000	500	500
21	Mixing and placing grout	CU YD	3000	2500	2500
22	Portland cement	BBL	320000	150000	170000
23	Steel for reinforcing concrete	LB	50000	45000	5000
24	Earth excavation not included in Item 1	CU YD	25000	23000	2000
25	Rock " " " " Items 2, 3 or 4	" "	800	400	400
26	Refilling and embanking	" "	25000	24000	1000
27	Removal of soil	" "	5000	5000	
28	Surface dressing of top soil	" "	3500	3500	
29	Impervious soil blankets and cores	" "	1000	1000	
30	Seeding and Grassing	ACRE	5	5	
31	Miscellaneous cast iron wrought iron and steel	LB	37500	35000	25000
32	Galvanizing	"	12500	11000	1500
33	Miscellaneous bronze, brass and copper	"	9000	7500	1500
34	Caring for and setting metalwork	"	120000	40000	80000
35	" " " " cast iron lining for Shaft 8	"	600000		600000
36	Tile pipe six inches and less in diameter	LIN FT	1800	1800	
37	Tile pipe eight to twelve inches inclusive in diameter	" "	2200	2200	
38	Ashlar masonry, except for copings	CU YD	250	250	
39	" " for copings	" "	60	58	2
40	Paving	" "	300	290	10
41	Crushed stone, gravel and sand	" "	7000	6900	100
42	Reinforced concrete ladders	LIN FT	80	30	50
43	Cost of Shaft 1 in addition to compensation under other items	LUMP	SUM		
44	Cost of Shaft 8 in addition to compensation under other items	"			
45	Cost of cir sect tunnel, Type B in add. to comps " " "	LIN FT	2000	1800	200
46	Fences for sanitary protection	" "	7000	6000	1000
47	Timber and lumber not in tunnel or shaft	M F B M	25	5	20
48	Medical and hospital services	MO	45	45	45
49	Sanitary services	"	45	45	45
50	Chlorinated lime	LB	20000	10000	10000
51	Liquid chlorine	"	18000	10000	
52	Chlorine dosing machines	MACH	4	4	
53	Locker houses	HOUSE	8	4	4
54	Cleaning up	LUMP	SUM		

*PROPOSAL A

ITEM	Winston & Co, Inc, Kingston NY PRICE	AMOUNT	Booth & Flinn Co, 1942 Forbes St, Pittsburgh, Pa PRICE	AMOUNT	T A Gillespie Co, 7 Dey St, New York, NY PRICE	AMOUNT	Keystone State Corp, Franklin Bank Bldg, Philadelphia, Pa PRICE	AMOUNT	Peter F Connolly, 8 Jackson Ave, Long Island City, NY PRICE	AMOUNT	Patrick McGovern Inc, 50 E 42nd St, New York, NY PRICE	AMOUNT
1	40	116[illegible]	1540	1540000	1500	1500000	1500	1500000	2000	2000000	860	860000
2	1140	10716000	3500	32900000	1500	14100000	2000	18800000	1800	16920000	1850	17390000
3	1140	604200000	1265	670450000	1375	728750000	1400	742000000	1300	689000000	1430	758600000
4	1140	1140000	800	800000	1375	1375000	2000	2000000	1800	1800000	3000	3000000
5	650	48100000	001	7400	300	22200000	[illegible]	14800000	750	55500000	200	14800000
6	1000	215000	880	189200	5000	1075000	5000	1075000	1600	344000	8000	1720000
7	1000	250000	860	215000	5000	1250000	4800	1200000	1500	375000	1000	250000
8	1000	75000	700	52500	2000	150000	2500	187500	500	37500	1000	75000
9	400	29600000	150	11100000	400	29600000	300	22200000	850	62900000	200	14800000
10	1000	4000000	2000	8000000	1100	4400000	852	3408000	1200	4800000	1560	6240000
11	690	117300000	1000	170000000	820	139400000	1200	204000000	1190	202300000	1250	212500000
12	1200	4200000	1400	4900000	1100	3850000	1500	5250000	1800	6300000	2000	7000000
13	300	300000	300	300000	300	300000	300	300000	300	300000	300	300000
14	6000	7500000	5000	6250000	10000	12500000	1050	13200000	1060	13200000	1500	18750000
15	6000	600000	5000	500000	1200	1200000	1300	1300000	1100	1100000	1500	1500000
16	200	1500000	250	1875000	1200	9000000	250	875000	400	3000000	1000	7500000
17	100	200000	035	70000	025	50000	050	100000	025	50000	020	40000
18	030	300000	030	300000	100	1000000	040	400000	025	250000	030	300000
19	180	180000	300	300000	200	200000	150	150000	020	20000	200	200000
20	050	50000	200	200000	170	170000	175	175000	300	300000	250	250000
21	600	1800000	500	1500000	500	1500000	200	600000	250	750000	500	1500000
22	270	86400000	265	84800000	255	81600000	325	104000000	250	80000000	350	112000000
23	006	300000	006	300000	006	300000	006	300000	018	500000	006	300000
24	130	3250000	250	6250000	250	6250000	225	5625000	200	5000000	700	17500000
25	500	400000	1500	[illegible]	500	400000	400	320000	400	320000	1000	800000
26	040	1000000	100	2500000	050	1250000	100	2500000	200	5000000	500	12500000
27	130	650000	100	500000	250	1250000	200	1000000	200	1000000	300	1500000
28	100	350000	200	700000	050	175000	300	1050000	300	1050000	300	1050000
29	100	100000	300	300000	030	30000	200	200000	500	500000	500	500000
30	1000	500000	1500	750000	2000	1000000	6000	3000000	3000	1500000	1800	900000
31	012	4500000	012	4500000	010	3750000	0075	2812500	020	7500000	010	3750000
32	004	50000	006	75000	010	125000	0175	218750	005	62500	005	62500
33	040	360000	100	900000	100	900000	075	675000	100	900000	050	450000
34	003	360000	005	600000	005	600000	003	360000	007	840000	003	360000
35	003	1800000	002	1200000	005	3000000	0015	900000	007	4200000	003	1800000
36	050	90000	100	180000	050	90000	150	270000	100	180000	050	90000
37	100	220000	125	275000	100	220000	200	440000	200	440000	150	330000
38	6000	1500000	2400	600000	11000	2750000	4000	1000000	7000	1750000	15000	3750000
39	8000	480000	5000	300000	11000	660000	10000	600000	10000	600000	20000	1200000
40	800	240000	1000	300000	500	150000	500	150000	500	150000	500	150000
41	250	1750000	200	1400000	300	2100000	150	1050000	400	2800000	300	2100000
42	400	32000	1500	120000	200	16000	300	24000	1500	120000	500	40000
43		300000		100		1500000		1000000		2800000		2500000
44		300000		100		1200000		1000000		2000000		2500000
45	200	400000	100	200000	2000	4000000	500	1000000	1000	2000000	1000	2000000
46	150	1050000	100	700000	130	910000	200	1400000	200	1400000	[illegible]	400000
47	10000	250000	10000	250000	15000	375000	7500	187500	12000	300000	15000	375000
48	1000	4500000	4000	18000000	5000	22500000	1000	4500000	1000	4500000	2000	9000000
49	800	3600000	3000	13500000	5000	22500000	1000	4500000	1000	4500000	2000	9000000
50	008	160000	010	200000	005	100000	030	600000	010	200000	005	100000
51	012	180000	010	180000	010	100000	030	300000	020	200000	012	120000
52	1000	400000	2500	1000000	3000	1200000	2000	800000	2000	800000	2000	800000
53	3500	2800000	6000	4800000	2500	2000000	6000	4800000	7500	6000000	10000	8000000
54		500000		270000		450000		750000		450000		500000
Total		$9339480.00		$10331866.00		$11856910.00		$11838532.50		$12104570.00		$13398775.00

**PROPOSAL B

ITEM	★ J D Porter, Porter Bldg, Portland, Ore PRICE	AMOUNT	Winston & Co, Inc, Kingston, NY PRICE	AMOUNT	† The Dravo Cont Co, Dravo Bldg, Pittsburgh, Pa PRICE	AMOUNT	Thos Connor & Sons & G L Tarlton, St Louis, Mo PRICE	AMOUNT	A Guthrie & Co Inc, 1209 Builders Exchange, St Paul, Minn PRICE	AMOUNT	Peter F Connolly, 8 Jackson Ave, Long Island City, NY PRICE	AMOUNT	Coleman Bros Inc, 245 State St, Boston, Mass PRICE	AMOUNT
1	800	800000	1150	1150000	800	800000	2300	2300000	3800	3800000	2800	2800000	600	600000
2	1200	4080000	1150	3910000	1000	3400000	3300	11220000	3200	10880000	1800	6120000	2000	6800000
3	1075	258000000	1150	276000000	1100	264000000	1175	282000000	1415	339600000	1320	316800000	1650	396000000
4	1200	600000	1150	575000	1200	600000	1000	500000	1415	707500	1000	500000	2800	1400000
5	200	6740000	650	21905000	400	13480000	250	8425000	125	4212500	700	23590000	1000	33700000
6	1575	338625	1000	215000	3500	752500	500	107500	5000	1075000	1600	344000	1300	279500
7														
8	100	2500	1000	25000	6000	150000	2000	50000	5000	125000	500	12500	1300	32500
9	260	8775000	400	13500000	700	23625000	200	6750000	230	7762500	950	32062500	1000	33750000
10	1000	2300000	1000	2300000	1150	2645000	1350	3105000	1225	2817500	1200	2760000	1500	3450000
11	750	57750000	690	53130000	800	61600000	1065	82005000	1225	94325000	1190	91630000	1300	100100000
12	1500	4500000	1200	3600000	1200	3600000	1650	4950000	2000	6000000	1800	5400000	1500	4500000
13	300	150000	300	150000	300	150000	300	150000	300	150000	300	150000	300	150000
14	3500	1750000	6000	3000000	1500	750000	1000	500000	1000	500000	1200	600000	1500	750000
15	800	40000	6000	300000	1650	82500	1000	50000	1000	50000	1100	55000	1000	50000
16	100	300000	200	600000	400	1200000	450	1350000	1200	3600000	400	1200000	400	1200000
17	050	50000	100	100000	060	60000	100	100000	100	100000	025	25000	025	25000
18	030	150000	030	150000	035	175000	025	125000	050	250000	025	125000	020	100000
19	100	50000	100	50000	300	150000	500	250000	100	50000	020	10000	050	25000
20	500	250000	050	25000	300	150000	300	150000	325	162500	300	150000	200	100000
21	700	1750000	600	1500000	1200	3000000	1500	3750000	1500	3750000	1500	3750000	1000	2500000
22	265	39750000	270	40500000	300	45000000	275	41250000	280	42000000	250	37500000	250	37500000
23	008	360000	006	270000	005	225000	005	225000	005	225000	010	450000	005	225000
24	100	2300000	130	2990000	350	8050000	225	5175000	100	2300000	200	4600000	100	2300000
25	400	160000	500	200000	600	240000	500	200000	500	200000	400	160000	700	280000
26	100	2400000	040	960000	100	2400000	125	3000000	100	2400000	200	4800000	100	2400000
27	100	500000	130	650000	085	425000	150	750000	100	500000	200	1000000	[illegible]	300000
28	100	350000	100	350000	120	420000	125	437500	100	350000	300	1630000	100	350000
29	500	500000	100	100000	175	175000	250	250000	300	300000	500	500000	100	120000
30	5000	250000	1000	50000	1750	87500	1000	50000	5000	250000	3000	150000	3000	150000
31	008	3000000	012	4500000	010	3500000	008	3000000	020	7500000	020	7500000	010	3500000
32	005	55000	004	44000	0035	38500	010	110000	006	66000	005	55000	005	55000
33	050	375000	040	300000	080	600000	050	375000	040	300000	100	750000	050	375000
34	003	120000	003	120000	003	120000	003	120000	003	120000	007	280000	003	120000
35														
36	125	225000	050	90000	050	90000	050	90000	030	54000	100	180000	050	90000
37	160	352000	100	220000	090	198000	100	220000	050	110000	200	440000	075	165000
38	3500	875000	6000	1500000	5500	1375000	5000	1250000	5400	1350000	7000	1750000	5000	1250000
39	5000	290000	8000	464000	7000	406000	6000	348000	10000	580000	10000	580000	7000	406000
40	500	145000	800	232000	700	203000	1000	290000	750	217500	500	145000	800	232000
41	300	2070000	250	1725000	250	1725000	250	1725000	550	3795000	400	2760000	400	2760000
42	250	7500	400	12000	350	10500	500	15000	300	9000	1500	45000	500	15000
43		100000		300000		500000		1500000		1000000		3000000		1000000
44														
45	1000	1800000	200	360000	090	162000	1500	2700000	1000	1800000	1000	1800000	500	900000
46	050	300000	150	900000	200	1200000	150	900000	050	300000	200	1200000	060	360000
47	7500	37500	10000	50000	9000	45000	10000	50000	11000	55000	14000	70000	10000	50000
48	1000	450000	5000	2250000	2500	1125000	5000	2250000	9000	4050000	1000	450000	5000	2250000
49	1000	450000	4000	1800000	6000	2700000	7000	3150000	1000	450000	10000	4500000	1000	450000
50	015	150000	008	80000	0045	45000	025	250000	004	40000	010	100000	010	100000
51	015	150000	012	120000	012	120000	025	250000	013	130000	020	200000	020	200000
52	2500	1000000	1000	400000	1200	480000	5000	2000000	5000	2000000	2000	800000	2000	800000
53	[illegible]	2800000	3500	1400000	3000	1200000	3500	1400000	2500	1000000	7500	3000000	7000	2800000
54		100000		400000		3000000		500000		1800000		3400000		1000000
Total		$4074981.25		$4632220.00		$4450860.00		$4033480.00		$3604630.00		$5785440.00		$6582850.00

***PROPOSAL C

ITEM	★★ Coughlan & Porter, 27 School St, Boston, Mass PRICE	AMOUNT	Winston & Co, Inc, Kingston, NY PRICE	AMOUNT	† The Dravo Cont Co, Dravo Bldg, Pittsburgh, Pa PRICE	AMOUNT	Thos Connor & Sons & G L Tarlton, St Louis, Mo PRICE	AMOUNT	A Guthrie & Co Inc, 1209 Builders Exchange, St Paul, Minn PRICE	AMOUNT	Peter F Connolly, 8 Jackson Ave, Long Island City, NY PRICE	AMOUNT
1												
2	1200	7200000	50	6900000	1200	7200000	3500	21000000	3200	19200000	1800	10800000
3	1100	319000000	1150	333500000	1100	319000000	1125	326250000	1300	377000000	1300	377000000
4	1200	600000	1150	575000	1200	600000	1000	500000	1300	650000	1000	500000
5	200	8060000	650	26195000	400	16120000	200	8060000	125	5037500	850	34255000
6												
7	1375	343750	1000	250000	3000	750000	500	125000	6000	1500000	1500	375000
8	700	35000	1000	50000	6000	300000	2000	100000	5000	250000	500	25000
9	350	14080500	400	16100000	700	28175000	200	8050000	220	8855000	900	36225000
10	1000	1700000	1000	1700000	1150	1955000	1350	2295000	1200	2040000	1200	2040000
11	800	74400000	700	65100000	850	79050000	1065	99045000	1200	111600000	1190	110670000
12	1000	500000	1200	600000	1250	625000	1350	675000	2800	1400000	1800	900000
13	300	150000	300	150000	300	150000	300	150000	300	150000	300	150000
14	2500	1875000	6000	4500000	1500	1125000	1000	750000	1000	750000	1200	900000
15	1000	50000	6000	300000	1650	82500	1000	50000	1000	50000	1100	55000
16	100	450000	300	1350000	400	1800000	450	2025000	1200	5400000	400	1800000
17	050	50000	100	100000	060	60000	100	100000	100	100000	025	25000
18	030	150000	030	150000	035	175000	025	125000	050	250000	025	125000
19	100	50000	100	50000	300	150000	500	250000	100	50000	020	10000
20	500	250000	050	25000	300	150000	300	150000	325	162500	300	150000
21	700	1750000	600	1500000	1200	3000000	1500	3750000	1500	3750000	1500	3750000
22	260	44200000	270	45900000	300	51000000	275	46750000	280	47600000	250	42500000
23	005	25000	006	30000	005	25000	005	25000	005	25000	010	50000
24	200	400000	200	400000	350	700000	200	400000	100	200000	200	400000
25	400	160000	500	200000	600	240000	500	200000	500	200000	400	160000
26	100	100000	050	50000	100	100000	150	150000	100	100000	200	200000
27												
28												
29												
30												
31	012	300000	012	300000	010	250000	010	250000	020	500000	020	500000
32	005	7500	004	6000	0035	5250	010	15000	006	9000	005	7500
33	030	78000	040	60000	180	120000	050	75000	040	60000	100	150000
34	003	240000	003	240000	003	240000	004	320000	003	240000	007	560000
35	002	1200000	[illegible]	1400000	0025	1500000	0025	1500000	003	1800000	007	4200000
36												
37												
38												
39	5000	10000	8000	16000	8000	16000	6000	12000	10000	20000	10000	20000
40	500	5000	800	8000	700	7000	1000	10000	750	7500	500	5000
41	400	40000	350	35000	250	25000	900	90000	500	50000	300	30000
42	250	12500	400	20000	350	17500	500	25000	300	15000	1500	75000
43												
44		100000		300000		500000		1500000		300000		2800000
45	1000	200000	200	40000	1000	200000	1500	300000	1200	240000	1000	200000
46	150	150000	150	150000	200	200000	450	450000	050	50000	200	200000
47	7500	150000	10000	200000	9000	180000	10000	200000	11000	220000	11000	220000
48	1000	450000	5000	2250000	2500	1125000	2000	900000	9000	4050000	1000	450000
49	1000	450000	4000	1800000	6000	2700000	7000	3150000	1000	450000	1000	450000
50	015	150000	008	80000	0045	45000	025	250000	004	40000	010	100000
51												
52												
53	6000	2400000	3500	1400000	3000	1200000	3500	1400000	2500	1000000	7500	3000000
54		100000		400000		3500000		500000		1800000		3400000
Total		$4799362.50		$5147800.00		$5352307.50		$5373520.00		$6072265.00		$6509275.00

* Proposal A is for entire Tunnel
** " B " " East portion
*** " C " " West "
† The Dravo Contracting Co will contract for entire tunnel at prices B and C. Total 3,812,167.50

★ Contract awarded on Contract 14 April 30, 1928
★★ Contract awarded on Contract 17 April 30, 1928

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1929 its

FOURTH ANNUAL REPORT

I. Organization and Administration

There was no change in the personnel of the Commission during the year. Davis B. Keniston continued as chairman, and Charles M. Davenport and Joseph H. Soliday as associate commissioners. R. Nelson Molt continued as secretary.

The clerical force of the Commission's office at Boston remained the same throughout the year, and three special agents, under the direction of the Commission, continued to care for property acquired by the Commission in the Swift River and Ware River areas. Real estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 125 employees during the year, with a maximum of 132 in August, 1929.

II. Engineering Department

Frank E. Winsor continued as chief engineer, with Karl R. Kennison as designing engineer and Walton H. Sears as mechanical engineer.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; and N. LeRoy Hammond, Swift River Reservoir Division.

The Commission reports with regret the death on June 1, 1929, of Walter Knowles, who as assistant engineer at the Framingham office, rendered efficient services in the construction of the Southern Sudbury Emergency Supply, and also later under Division Engineer N. LeRoy Hammond in the Swift River Reservoir Division.

X. H. Goodnough, Chief Engineer of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, continued as consulting engineers. Charles T. Main of Boston was employed from time to time as consulting engineer on mill and water power damages, and Doctor Charles P. Berkey of Columbia University continued as geologist. Other consultants were employed from time to time as needed.

III. Offices

The office of the Commission and of the Chief Engineer continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston. The three division offices for the Wachusett-Coldbrook Tunnel, the Coldbrook-Swift Tunnel and the Swift River Reservoir Divisions continued at Holden Center, Hardwick Center and Enfield, respectively. The laboratory for water analysis, established in 1928, continued at Springfield.

IV. Real Estate

During the year 226 new applications to the Commission were added to the 1,210 previously received from the owners of real estate located in and near the Swift River Valley, making a total to date of 1,436 applications, seeking to sell to the Commission a total of 58,989 acres. Of this total acreage the Commission has concluded the purchase of, or has under option, a total of 38,922 acres. Further details appear in the attached tables.

Some land was acquired also along the line of the Wachusett-Coldbrook Tunnel and in the Ware River watershed above the Intake Works at Coldbrook for sanitary protection.

The Commission continued, through duly appointed agents, the direction of the town government of the town of Prescott, as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

V. Progress

(*a*) *General.* — The United States War Department, on May 17, 1929, advised the Commission of the Department's decision, in response to the Commission's application for diversion of the waters of the Swift River, in accordance with the provisions of Chapter 321 of the Acts of 1927, that,

"From the studies of past records it appears there will be no substantial alteration or modification of the condition or navigable capacity of the channel of the navigable portion of the Connecticut River if the flow of water from the Swift River as provided in the terms of Chapter 321 of the Acts of 1927 (Massachusetts) be augmented during the critical period from June 1 to November 30, both inclusive, so that the measured rate of discharge on the Swift River shall be 70 cubic feet per second on such days as the U. S. Geological Survey gauge at Sunderland, Massachusetts, indicates the discharge of the Connecticut River at that point to be less than 4,900 cubic feet per second and more than 4,650 cubic feet per second, and shall be further augmented so that the measured rate of discharge past the impounding dam on the Swift River shall be 110 cubic feet per second on such days as the Geological Survey gauge at Sunderland, Massachusetts, indicates the discharge of the Connecticut River at that point to be 4,650 cubic feet per second or less."

The bill in Equity filed by the State of Connecticut in the United States Supreme Court against the Commonwealth of Massachusetts, objecting to the diversions from the Ware River and Swift River, authorized by the Massachusetts Legislature is still pending.

(*b*) *Southern Sudbury Emergency Supply.*—The Commission has consummated the settlement of practically all outstanding claims for taking of real estate and diversion damages on the Southern Sudbury Emergency Supply.

(*c*) *Ware River Supply.* — During the past year work was continued by the West Construction Co., Assignee, under two contracts, numbered 14 and 17, for the construction of the Wachusett-Coldbrook Tunnel, and approximately 9.0 miles of tunnel were excavated. The Outlet Works of the Wachusett-Coldbrook Tunnel to the upper waters of the Wachusett Reservoir at Shaft No. 1, West Boylston, were partly completed. A contract for the construction of a low diversion dam across the Ware River at the White Valley mill pond in Barre, for diverting the waters, permitted to be diverted, of the Ware River into Shaft No. 8, and for the construction of the substructure of the Intake Works was awarded to J. W. Bishop & Co., of Worcester, Mass. Work was in progress under this contract.

(*d*) *Swift River Supply.* — Real estate and topographical surveys were continued during the year. Work was continued on the census of burials in cemeteries, together with records of inscriptions on headstones and monuments. Upon request some bodies were removed from the reservoir area and interred in other cemeteries.

VI. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

VII. Other Reports

The report of the Chief Engineer is herewith presented. It includes a summary of the information of geological interest, in accordance with the requirements of Section 2 of Chapter 321 of the Acts of 1927.

Respectfully submitted,

DAVIS B. KENISTON, *Chairman*
CHARLES M. DAVENPORT, *Associate Commissioner*
JOSEPH H. SOLIDAY, *Associate Commissioner*
Metropolitan District Water Supply Commission

24 School Street, Boston, Massachusetts,
December 27, 1929.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1929.

ORGANIZATION

In numbers the engineering organization has not materially changed during the year.

Karl R. Kennison, Designing Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, preparation of contract specifications, contract and working drawings. Charles L. Coburn and Stanley M. Dore were promoted to Assistant Designing Engineers.

Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. He has assisted in the design of work of a mechanical engineering nature and in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Swift River Reservoir Division.

Walter H. Junkins, Chemist, continued in charge of the Springfield Laboratory.

X. H. Goodnough, Chief Engineer of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, continued as Consulting Engineers. Charles T. Main, consulting engineer of Boston, has advised on mill and water power damages. Dr. Charles P. Berkey of Columbia University has advised on geological matters. Other experts were employed from time to time as required.

The employees under the direction of the Chief Engineer at the end of the year and of the preceding year were as follows:

PERSONNEL OF ENGINEERING DEPARTMENT

CLASSIFICATION	Nov. 30, 1928	Nov. 30, 1929
HEADQUARTERS OFFICE, CHIEF ENGINEER AND DESIGNING DIVISION:		
Chief Engineer	1	1
Designing Engineer	1	1
Mechanical Engineer	1	1
Assistant Designing Engineers	–	2
Assistant Engineers	11	9
Draftsmen	9	7
Instrumentmen	2	1
Senior Stenographer	1	1
Stenographers	3	3
Clerks	2	2
File Clerk	1	2
Office Boy	1	1
	33	31
HOLDEN OFFICE, WACHUSETT-COLDBROOK TUNNEL DIVISION:		
Division Engineer	1	1
Assistant Engineers	5	8
Draftsmen	2	2
Instrumentmen	5	3
Rodmen	5	3
Axemen	4	7
Inspectors	8	9
Stenographer	1	1
	31	34
HARDWICK OFFICE, COLDBROOK-SWIFT TUNNEL DIVISION:		
Division Engineer	1	1
Assistant Engineers	5	4
Draftsmen	1	2
Instrumentmen	1	4
Rodmen	8	4
Axmen	4	4
Inspectors	1	3
Gage Tender	–	1
Stenographer	–	1
	21	24

Classification	Nov. 30, 1928	Nov. 30, 1929
Enfield Office, Swift River Reservoir Division:		
Division Engineer	1	1
Assistant Engineers	9	6
Draftsmen	3	1
Instrumentmen	7	6
Rodmen	11	7
Axemen	7	4
Inspector	1	–
Caretaker	–	1
Stenographer	–	1
	39	27
Springfield Laboratory:		
Chemist	1	1
Assistant Engineer	1	1
Assistant Chemist	1	1
Instrumentman	1	1
Boatman	1	1
Clerk	1	1
	6	6
Total Engineering Force	130	122

The maximum force during the year was 132, during the weeks ending August 24 and 31. The minimum force was 118 during the week ending November 2. The average force for the year was 125.

Offices

The office of the Chief Engineer and Designing Division was continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Swift River Reservoir Division was continued in Enfield in the Felton Block until December 27, 1928, when the office was moved to property of the Commission formerly known as Frances W. Chandler House on Quabbin Road in Enfield. Necessary changes were made in this house and a new three-story fireproof vault was built. The laboratory for water analysis was continued in the Markarian Building, at 175 State Street, Springfield.

Headquarters Office

Summary of the Year's Work

Application for Diversion from Swift River. — Studies of the effect of the proposed diversion for the Metropolitan District of waters from the Ware and Swift Rivers upon the flow of the Connecticut River were continued. The War Department, under date of May 17, 1929, replied to the Commission's application to divert the waters of the Swift River as authorized by Chapter 321, Acts of 1927, by finding that "there will be no substantial alteration or modification of the condition or navigable capacity of the channel of the navigable portion of the Connecticut River if the flow of water from the Swift River as provided in the terms of Chapter 321, of the Acts of 1927 (Massachusetts), be augmented during the critical period from June 1, to November 30, both inclusive, so that the measured rate of discharge on the Swift River shall be 70 cubic feet per second on such days as the United States Geological Survey gage at Sunderland, Massachusetts, indicates the discharge of the Connecticut River at that point to be less than 4,900 cubic feet per second and more than 4,650 cubic feet per second and shall be further augmented so that the measured rate of discharge past the impounding dam on the Swift River shall be 110 cubic feet per second on such days as the Geological Survey gage at Sunderland, Massachusetts, indicates the discharge on the Connecticut River at that point to be 4,650 cubic feet per second or less."

Real Estate. — In the Swift River Reservoir area, 8,870 acres were offered for sale by their owners this year, making a total so offered to date of 58,989 acres. Reports and recommendations were submitted to the Commission with respect

to purchasing the same. Preliminary studies were continued of highway and cemetery locations.

One taking plan covering 16 parcels of land in the town of Barre for the Coldbrook-Swift Tunnel was prepared and filed during the year.

Contracts and Specifications. — Working drawings for Contracts 14 and 17 for constructing the Wachusett-Coldbrook Tunnel were prepared and issued.

Contract 18, for which specifications and plans were completed early in the year for furnishing cast-iron plates for lining the Ware River intake shaft and other castings required for the intake control works, was executed January 8.

Plans and specifications were completed for Contract 19, for constructing a low diversion dam and the substructure of the building for the Ware River Intake Works at Shaft 8, of the Wachusett-Coldbrook Tunnel in the town of Barre. The contract was executed on July 23. Subsequently working drawings were prepared covering details of the work of construction.

Plans and specifications were prepared for Contract 22 for furnishing and installing an Unwatering Pump in Shaft 1 of the Wachusett-Coldbrook Tunnel in the town of West Boylston. The contract was executed on November 12.

Plans and specifications were prepared for Contract 23 for making borings at the proposed sites of the main dam and of the dike of the Swift River Reservoir, and at the west portal of the proposed Coldbrook-Swift Tunnel. This contract was executed on November 5.

Inspection and Tests. — E. L. Conwell and Company of Philadelphia, Pa., continued the testing of cement. Concrete cylinders and mortar cubes were tested for compressive strength and steel reinforcement bars were tested at the laboratory of the Worcester Polytechnic Institute. The inspection of the castings made under Contract 18 was made by the engineering force.

William R. Conard (and predecessor, Conard & Buzby) of Burlington, New Jersey, has made mill inspection and tests of sluice gates and control valves and mechanism required for the Ware River Intake Works at Shaft 8, and of steel linings, valves and other metal work for the Outlet Works at Shaft 1 of the Wachusett-Coldbrook Tunnel.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey. Additional discharge measurements were made from time to time to define the rating curve more exactly, particularly in the winter during the ice conditions.

The gaging station at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and also with the United States Geological Survey. Additional discharge measurements were made during the year to define the discharge curves of the water wheels and the dam.

The gaging station rated in 1927 at the water power plant of the Boston Duck Mills of the Otis Company at Bondsville was continued.

The gaging station on the Connecticut River at Thompsonville, Connecticut, located at the "Enfield Dam," so called, was continued in cooperation with the United States Geological Survey. Additional measurements were made to better define the rating curves of both the dam and canal.

In connection with the sanitary survey of the Ware, Swift and Chicopee Rivers, various points on these rivers were established as temporary stream gaging stations and observations of flow taken during the periods of sampling.

Design of Structures

Shaft 1. Tunnel Unwatering Pump. — Studies were made of equipment for unwatering the Wachusett-Coldbrook Tunnel. A length of about 18,000 feet at the east end of the tunnel is depressed below the hydraulic grade, to insure a sufficient cover of sound rock. On this account approximately 28 million gallons of water cannot be drained by gravity into the Wachusett Reservoir when it is full to its spillway level, and approximately 20 million gallons will still remain after it is drawn down below the tunnel outlet. Unwatering equipment will be required to insure the removal within the required time of the water which cannot be drained by gravity.

The pump will be a single stage centrifugal pump delivering 20 mil. gals. daily against a total head of 205 ft., at a speed of 1,170 rev. per min., driven by a 900

H.P. 2,200-volt motor of the squirrel cage induction type. A travelling crane to be installed later in the superstructure will be designed to lift the motor out of the shaft for storage at the upper level if desired. Contract 22 will include also an air blower to supply 6,000 cu. ft. per min. to the bottom of the shaft.

To maintain the pump shaft itself in an unwatered condition, a sump pump of the deep-well type, with a capacity of 80 gals. per min., has been purchased and will be installed as soon as the shaft lining under Contract 14 is completed.

Designs were made for a special 20-inch solid bronze valve on the inlet of the unwatering pump, intended for operation from either the bottom or top of the pump shaft. This valve was purchased, and will be installed under Contract 14.

Tunnel Bulkhead. — A steel bulkhead was designed to be built into the tunnel west of the Ware River Intake at Shaft 8. This bulkhead will have gates so hinged as to allow a flow in the easterly direction only, and will serve a double purpose: First, to allow construction to proceed on the future extension of the proposed tunnel westerly to the Swift River Reservoir without interference with the use of the Wachusett-Coldbrook Tunnel for diverting flows of the Ware River into the Wachusett Reservoir; second, to allow if later required a preliminary diversion of water from the Swift River into the Wachusett Reservoir and at the same time prevent Ware River diversions from flowing westerly through the proposed tunnel extension into the Swift River Reservoir before the latter is completed and ready for storage. This bulkhead will be entirely removed after the Swift River Reservoir is completed.

Shaft 8. Ware River Intake Works. — Further studies were made of the works required for diverting the Ware River into the Wachusett-Coldbrook Tunnel at Shaft 8, particularly of details of control valves and equipment. One 72-inch and three 60-inch Dow disc valves with automatic operating devices will be installed under Contract 19.

Each valve will be set with its disc revolving on a horizontal axis and will be supported on a base casting which in turn will be set directly over a nozzle casting of irregular shape, designed to direct the discharge tangentially against the upper row of shaft lining plates. The cast iron shaft lining plates, 300 in number, are designed to be erected in 50 rings, 18′-8″ inside diameter and 3′-8⅜″ high, each ring having six plates flanged and bolted together. The plates are cast with interlocking lugs and are designed to fit together accurately without machine work. The only projection on the inside is a helical ring which serves as a guide for the water and which consists of one diagonal vein from corner to corner of each plate projecting from six to ten inches and serving also to stiffen the casting.

The diversion dam has been designed as a low spillway consisting mainly of a thin circular arch with a radius of 52.5 feet and with a crest at elevation 657.0 above Boston City Base. The length of the spillway will be 174 feet at this elevation including 34 feet along the top of the abutment sections. The circular spillway between the abutment sections is designed to discharge into a pool about elevation 640 which is slightly higher than the level of the river a little downstream and the more massive abutment sections are stepped on the downstream face and furnish additional spillway length discharging directly into the river below the pool. The abutment sections of the spillway in turn abut against retaining walls on either bank which extend to a height ten feet above the spillway level. On the south bank an earth dike with its top at elevation 667 extends into the hillside, as far as the Boston & Albany Railroad track and on the north bank the dam abuts directly against the intake building substructure. The siphon spillways which discharge into the tunnel are designed with crests at elevation 656 or one foot lower than the flood spillway of the diversion dam. All exposed concrete above the water level is designed with a facing of granite.

Springfield Laboratory

At the laboratory in Springfield the analysis of water samples taken in the Connecticut River and its tributaries was continued. Studies were also made of quality of water in the Ware, Swift, and Chicopee rivers.

Wachusett-Coldbrook Tunnel Division — Holden Office

The Wachusett-Coldbrook Tunnel Division continued in charge of the construction of the Wachusett-Coldbrook Tunnel, with the exception of Shaft 8.

The division office was continued at Holden Center and six field offices at Shafts 1, 2, 4, 5, 6, and 7.

Office Work

Property surveys were computed and mapped, topographical notes reduced and plotted; tunnel sections were plotted and excavation volumes computed therefrom; semi-monthly estimates were prepared for Contracts 14 and 17, and monthly estimates for Contract 10.

Geological field notes and specimens were prepared for a permanent geological record.

Preliminary studies were made of the character of materials available for concrete aggregates from the tunnel and shaft excavations. Records were kept of the cost of the different units of equipment used at each of the shafts, as provided in Contracts 14 and 17.

Field Work

Property surveys were made in the town of Rutland, and in the vicinity of Shaft 2 in the town of Holden. A line of levels, 22 miles in length, was run in connection with studies of sewage disposal from institutions in Rutland. A study of the sanitary conditions of recreation camps in the Ware River drainage area and also of several ponds in that watershed was made.

Lines and grades were given for construction work on the Wachusett-Coldbrook Tunnel.

Surveys for the location of property bounds were made and such bounds set as required.

Photographs of the construction work and of rock formations of geological interest in the tunnel were taken.

Weekly observations of water color samples were made at a number of stations along the Ware River and its tributaries above the intake works.

The State Department of Public Health with cooperation of this division continued the analysis of samples of drinking water used in the different contractors' camps and of the effluent from the sewage disposal plants at various institutions in Rutland and also made seasonal investigations of mosquitoes at the different construction camp sites with particular reference to the prevention of malaria.

Progress of Contracts

Contract 10. — Contract 10 with the New England Power Company, for constructing, maintaining and operating a 22,000-volt transmission line along the Wachusett-Coldbrook Tunnel line, was in force throughout the year. The cost of operation and maintenance for the twelve months ending October 1, was $8,496.96.

Electric power was purchased from this company by the contractors on Contracts 14 and 17. The total power furnished during the year was 15,865,400 KWH including line and transformer losses. This total after line losses (but including transformer losses) was distributed to the different shafts as follows:

	KWH
Shaft 1	320,271
Shaft 2	2,970,628
Shaft 3	16,734
Shaft 4	2,956,800
Shaft 5	2,298,454
Shaft 6	1,641,098
Shaft 7	2,652,154
Shaft 8	2,729,464
Total	15,585,603

During a very severe electrical disturbance on June 15, for a period of about five hours, no power was available, but with this exception power was furnished throughout the year with only minor interruptions.

Wachusett-Coldbrook Tunnel. — Work on the tunnel was prosecuted throughout the year under Contracts 14 and 17 by the West Construction Company, who continued to lease from the Commission various buildings at West Rutland as general headquarters. The contractor continued to employ local physicians who made weekly reports on the health of the contractors' employees and on the sanitary condition at each of the contractors' camps.

Contract 14. — Contract 14 is for the construction of the east portion of the Wachusett-Coldbrook Tunnel through West Boylston, Holden and Rutland, and extends from Shaft 1 at the upper end of the Wachusett Reservoir near Oakdale to midway between Shafts 4 and 5 in Rutland. At the end of the year about 51% of the value of the work had been completed. This included the completion of Shaft 1 excavation and preliminary concrete lining, and 515 feet of concrete lining of the tunnel adjacent to Shaft 1. During the year about 75% of the steel lining for the pump and waterway shafts at Shaft 1 was placed and concrete was placed outside the steel linings for a distance of 184 feet above the bottom of the pump shaft. The masonry was completed in the walls of the outlet channel, concrete piers, and curtain wall.

During the year a total length of 19,333 feet of tunnel was excavated, making a total to date of 21,981 feet under this contract and a total length under this and previous contracts of 25,791 feet. About 7,911 feet remained to be excavated. The value of work included in contract estimates during the year was $1,563,900.64, or a total to November 15, the date of the latest estimate, of $1,832,400.79, of which 90% has been approved for payment.

Shaft 1, and Outlet Channel. — At the beginning of the year excavation had reached a total depth of 158.5 feet at elevation 247.0 and on January 1, was completed to a depth of 222.8 feet at elevation 182.67, the bottom of the pump shaft. The preliminary concrete lining had previously been placed down to elevation 273.0 and on December 16, the last section of this lining was placed, the bottom being at elevation 217.0. For the remaining depth of shaft the rock continued to be of excellent character and carried no additional water. Tunnel excavation toward Shaft 2 began on December 22, and continued until June 5, when excavation was suspended. About 511 feet of excavation for the circular type, adjacent to the shaft, 15 feet for a transition section and 310 feet of the horseshoe type, making a total of 836 feet was completed. Concrete lining of the circular type and transition section began on June 25, and was completed on August 15.

The excavation of the outlet channel waterway was completed during the week ending February 1, and the construction of the channel walls was completed during the week ending March 9. The stone for the ashlar masonry facing was obtained from quarries in Fitchburg, Mass.

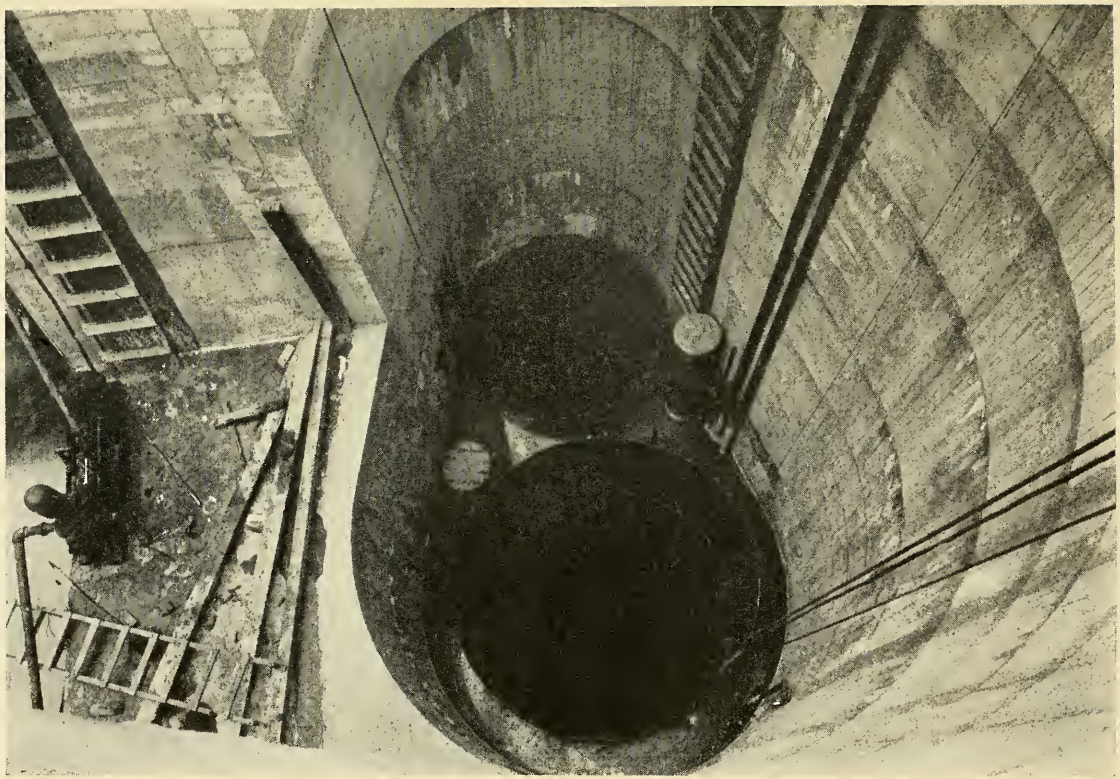
The first section of steel lining for the pump shaft was received at Shaft 1 on August 27. On September 21, the plates for the bottom section of the enlarged pump chamber were placed and bolted into position, and later were riveted and caulked. The cast iron pump discharge and ventilation pipe lines were carried up with the steel lining and embedded in the concrete partition between the pump shaft and waterway shaft. At a point about 127 feet above the bottom of the pump shaft, the steel lining for the waterway shaft begins. Sections of this lining were delivered unassembled at the shaft, in average lengths of about 7 feet. From the lower end of the steel lining of the waterway shaft both this lining and that of the pump shaft were brought up as nearly as possible at the same level, and the concrete around the steel was brought up as before. The average weekly progress for construction of the lower 127 feet of pump shaft was about 18.1 feet. The average weekly progress for construction of the upper shaft and waterway adjacent to it, including steel lining for both shafts, placing concrete on the outside of the two shafts and also placing pump discharge and ventilating pipes was about 18.8 feet.

The contractor's force averaged 35 men throughout the year.

The following items of plant equipment were added during the year: One air blower rated at 3,600 cu. ft. of free air per min. and driven by a 20 H.P. motor; a welding outfit and carpenter shop equipment.

Shaft 2. — Excavation at this shaft has progressed as follows:

Location	Total Excavation under a previous contract	Total Excavation under Contract 14		Total Excavation to Nov. 30, 1929
		to Nov. 30, 1928	Year ending Nov. 30, 1929	
East Heading	868 ft.	742 ft.	4,360 ft.	5,970 ft.
West Heading	903 ft.	1,018 ft.	5,254 ft.	7,175 ft.
Total	1,771 ft.	1,760 ft.	9,614 ft.	13,145 ft.



Contract 14. — Steel Linings in Tunnel Outlet, Shaft 1. The larger opening is the waterway, and the smaller opening the pump shaft.

The full heading method of excavation was continued throughout the year with no material change. Drill carriages such as were previously used at Shaft 4 were installed. These carriages allowed five drills to be used at once and enabled a crew to drill one heading completely while another crew were mucking the opposite heading. After the introduction of the carriages three drill shifts and three mucking shifts were employed and continued for the remainder of the year.

The average weekly progress on tunnel excavation during the period from December 1, 1928, to February 23, was easterly 32.1 feet and westerly 104.0 feet, and during the period from February 23, to November 30, was easterly 99.4 feet and westerly 100.1 feet. The maximum progress was in the week ending October 19, when 110.0 feet were excavated in the east section and 117.0 feet in the west section.

The contractor's force averaged 119 men throughout the year.

There has been no material change in plant items during the year. One additional five-ton storage battery locomotive was transferred from Shaft 4. In all, 15 pumps were used in connection with tunnel construction. The largest has a rated capacity of 700 gals. per min. under a 100 ft. head, driven by a 30 H.P. motor. The combined compressor capacity was 1,926 cu. ft. per min.

Shaft 3. — Shaft 3 was kept unwatered until December 22, 1928, when the contractor dismantled the pumping plant. It is expected that the remaining tunnel between Shafts 2 and 4 can be completed in the time specified without the resumption of further excavation from this shaft. The distance excavated (under a previous contract) is 630 feet easterly and 566 feet westerly, a total of 1,196 feet.

Shaft 4. — Excavation at this shaft has progressed as follows:

Location	Total Excavation under a previous contract	Total Excavation under Contract 14		Total Excavation to Nov. 30, 1929
		to Nov. 30, 1928	Year Ending Nov. 30, 1929	
East Heading	442 ft.	529 ft.	4,610 ft.	5,581 ft.
West Heading	401 ft.	359 ft.	4,273 ft.	5,033 ft.
Total	843 ft.	888 ft.	8,883 ft.	10,614 ft.

At the beginning of the year tunnel excavations were carried on by the top heading and bench method. In this method of excavation four drilling shifts were used and three mucking shifts which alternated between the two headings. Drill carriages of the type used subsequently at the heading in Shaft 2 were installed in the west and east headings respectively. After the installation of these carriages, tunnel driving operations continued using the full heading method and three shifts of drilling and mucking, the procedure being similar to that described for Shaft 2.

In the east heading, about 2,100 feet from the shaft, timbers for temporary roof support were erected for a distance of 38 feet.

The rock in portions of the roof of the west heading beginning at a point about 2,400 feet from the shaft, while sound when first exposed, loosened under exposure to the air and the contractor was permitted to cover about 2,615 linear feet of tunnel roof with cement mortar, or a "gunite," using a cement gun operated with compressed air. The mortar was applied in two or three coats, each with a thickness of about ¾ inch.

The average weekly progress on tunnel excavation was easterly 88.7 feet and westerly 82.2 feet, the maximum progress being in the week ending June 29, when 131.0 feet were excavated in the east section and 106.5 feet in the west section.

The contractor's force averaged 125 men.

There has been no material change in plant items during the year. One 3½ ton gasoline locomotive was transferred from Shaft 2. In all eleven pumps were used in connection with tunnel construction. The largest has a rated capacity of 700 gals. per min. under a 100 ft. head, driven by a 30 H.P. motor. The combined compressor capacity was 1,926 cu. ft. per min.

The total work done and materials furnished to date under the principal items of Contract 14 were as follows:

	Shaft 1	Shaft 2	Shaft 4
Earth excavation for shafts (cu. yds.)	1,108	–	–
Rock excavation in shafts and in tunnel within 50′ of shafts (cu. yds.)	3,175	–	–
Excavation in tunnel, except within 50′ of shafts (cu. yds.)	5,935	77,033	67,138
Shaft and tunnel drainage (lin. ft.)	1,035	7,904	6,752
Forms for preliminary concrete lining, shaft 1 (lin. ft.)	188	–	–
Forms for concrete lining in tunnel (lin. ft.)	526	–	–
Concrete masonry in shafts (cu. yds.)	1,548	–	–
Concrete masonry in tunnel (cu. yds.)	1,595	–	–
Concrete masonry not in shafts and tunnel (cu. yds.)	2,339	27	17
Temporary timbering in tunnel (M ft. B.M.)	–	–	4.25
Portland Cement (bbls.)	9,612	35	586
Earth excavation except for shafts (cu. yds.)	10,480	2,260	5,616
Rock excavation except in shafts or tunnel (cu. yds.)	796	35	771
Refilling and embankment (cu. yds.)	8,110	6,220	4,193
Miscellaneous cast iron, wrought iron and steel (lbs.)	265,889	2,879	331
The Contractor's total force averaged (men)	35	119	125

Contract 17. — Contract 17 is for the construction of the west portion of the Wachusett-Coldbrook Tunnel through Rutland, Oakham and Barre, and extends westerly from the work covered by Contract 14, the work being prosecuted from Shafts 5, 6, 7 and 8.

The top heading and bench method of excavation was continued at all shafts throughout the year, but the method of handling the muck has changed from time to time. At the end of the year about 63% of the value of the work had been completed.

During the year a total length of 28,109 feet of tunnel was excavated, making a total to date of 34,558 feet, under Contract 17, or a total length under this and previous contracts of 38,987 feet. About 1,569 feet remained to be excavated east of Shaft 8 and 4,355 feet have been excavated west of Shaft 8.

The value of work included in contract estimates during the year was $2,166,-437.99, or a total to November 15, the date of the latest estimate, of $2,658,041.63, of which 90% has been approved for payment.

Shaft 5. — Excavation at this shaft has progressed as follows:

Location	Total Excavation under a previous contract	Total Excavation under Contract 17		Total Excavation to Nov. 30, 1929
		to Nov. 30, 1928	Year Ending Nov. 30, 1929	
East Heading	670 ft.	956 ft.	4,193 ft.	5,819 ft.
West Heading	697 ft.	1,000 ft.	4,270 ft.	5,967 ft.
Total	1,367 ft.	1,956 ft.	8,463 ft.	11,786 ft.

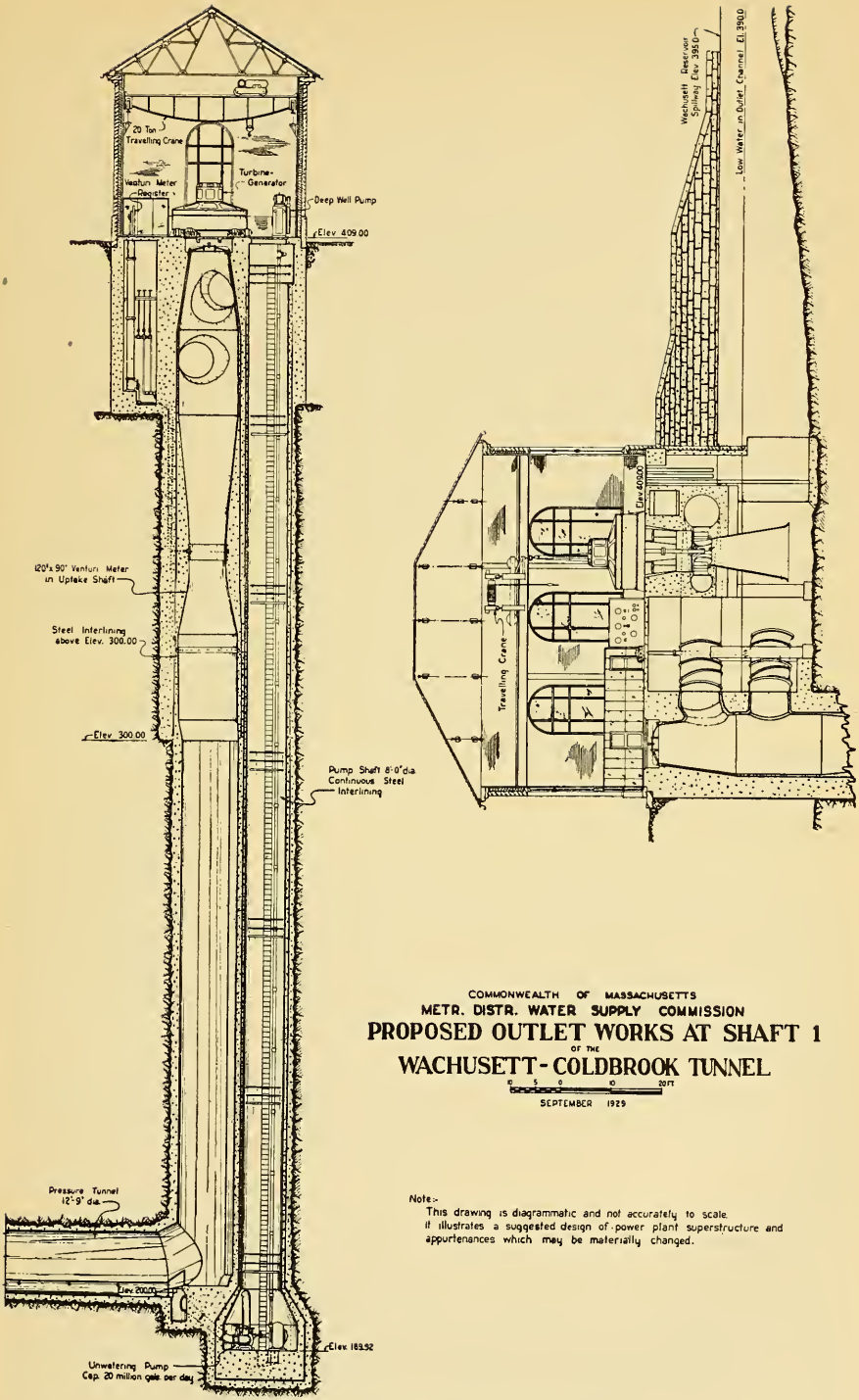
The rock from this shaft has continued to be of good quality for tunnelling, except that the rock in the tunnel roof near the east heading appears quite similar to that in the west end of the tunnel at Shaft 4. In this section frequent scaling was necessary, but no gunite or other support has been placed.

On November 15, excavation had reached the easterly limit of Contract 17, a point half way between Shafts 4 and 5, and excavation in this heading was suspended and final trimming and grading the tunnel was begun. This work consisted of grading the invert to required lines and trimming the tunnel at those points where the rock had broken inside of the lines specified. The average weekly progress on tunnel excavation easterly was 83.9 feet and westerly 82.1 feet, the maximum progress being in the week ending December 8, when 90.5 feet were excavated in the east section and 101.5 feet in the west section.

The contractor's force averaged 90 men per day, two shifts being employed.

There was no material change in the plant items during the year. In all five pumps were used in connection with tunnel construction. The largest has a rated capacity of 300 gals. per min. under a 670 ft. head, driven by a 100 H. P.motor. The addition of an air compressor driven by a 150 H.P. motor made the combined compressor capacity 2,341 cu. ft. per min.

Contract 17. — After holing through between Shafts 6 and 7.



Profile of Proposed Outlet Works at Shaft 1.

Shaft 6. — Excavation at this shaft has progressed as follows:

Location	Total Excavation under a previous contract	Total Excavation under Contract 17 to Nov. 30, 1928	Total Excavation under Contract 17 Year Ending Nov. 30, 1929	Total Excavation to Nov. 30, 1929
East Heading	671 ft.	1,060 ft.	3,042 ft.	4,773 ft.
West Heading	669 ft.	1,117 ft.	2,946 ft.	4,732 ft.
Total	1,340 ft.	2,177 ft.	5,988 ft.	9,505 ft.

Hand methods of mucking were substituted for mechanical methods in the west heading on March 24, and hand methods were used throughout the year in the east heading.

The rock continued of good quality for tunnelling, no timber supports of any nature being required. Late in July progress was retarded by water encountered in the east heading necessitating a rearrangement of pumping equipment. Tunnel driving was discontinued in the west heading on September 2, and in the east heading on September 22, leaving the remaining adjoining unexcavated portions to be driven from Shafts 7 and 5 respectively, and final trimming and grading of the tunnel was begun preparatory to placing concrete lining. At the end of the year approximately 6,840 feet had been prepared ready for placing of concrete.

The average weekly progress on tunnel excavation easterly was 72.4 feet and westerly 75.0 feet, the maximum progress being in the week ending June 29, when 93.0 feet were excavated in the east section and 94.0 feet in the west section.

The contractor's force to September 21, averaged 97 men and for the year 84 men per day, two shifts being employed.

There has been no material change in plant items during the year. In all seven pumps were used in connection with tunnel construction. The largest has a rated capacity of 300 gals. per min. under a 670 ft. head driven by a 100 H.P. motor. The combined compressor capacity was 1,511 cu. ft. per min.

Shaft 7. — Excavation at this shaft has progressed as follows:

Location	Total Excavation under a previous contract	Total Excavation under Contract 17 to Nov. 30, 1928	Total Excavation under Contract 17 Year Ending Nov. 30, 1929	Total Excavation to Nov. 30, 1929
East Heading	861 ft.	908 ft.	2,731 ft.	4,500 ft.
West Heading	861 ft.	1,130 ft.	3,007 ft.	4,998 ft.
Total	1,722 ft.	2,038 ft.	5,738 ft.	9,498 ft.

On January 15, a change was made in the drilling and mucking schedule; from this time on the drilling and shooting of both headings being done during the night shift and mucking during the day shift. Previous to this, the schedule of operation was similar to that used at Shafts 5 and 6. Each shift was depended upon to complete its schedule of required work. A slight increase in depth of holes in the heading to 10 feet resulted in as large a volume of muck as could be excavated in one full day shift without any overlapping. Mechanical mucking was continued throughout the year.

On October 25, at 3.00 A.M., the east heading was holed through to the west heading of Shaft 6 at station 574+52.67, the grade checking to 0.07 foot and line to 0.31 foot. Final grading of invert and trimming was begun and at the end of the year 1,600 feet of tunnel had been prepared substantially ready for placing of concrete lining.

The character of rock continued to be satisfactory, no support of any kind being necessary.

The average weekly progress on tunnel excavation easterly was 58.1 feet and westerly 57.6 feet, the maximum progress being in the week ending December 22, when 69.5 feet were excavated in the east section and 67.5 feet in the west section.

The contractor's force averaged 67 men per day, two shifts being employed.

Work was begun on the installation of concrete plant on November 8. By the end of the year the following plant had been received at the shaft; 1 primary and 1 secondary crushing plant each having a rated capacity of 100 cu. yds. of crushed rock per hour, two weighing hoppers for fine and coarse aggregates, and one screen (60″ diam. x 18′).

The weighing hoppers were installed, and a heavy timbered connecting gallery for belt conveyor constructed. This conveyor is designed to carry the dry material in batches to the head of the shaft. At the end of the year work was in progress on the construction of foundations for the crushing plant, supports for the conveyors, and dragline tower. A similar screen has been delivered at Shaft 5, and some work done on grading for access road and for foundation.

Otherwise than stated above there has been no material change in plant items during the year. One mucking machine was added. In all eleven pumps were used in connection with tunnel construction. The largest has a rated capacity of 450 gals. per min. under a 160-ft. head and is driven by a 30 H.P. motor. The combined compressor capacity was 1,532 cu. ft. per min.

Shaft 8. — (Under the supervision of the Coldbrook-Swift Tunnel Division.) Excavation at this shaft has progressed as follows:

Location	Total Excavation to November 30, 1928	Total Excavation during year ending November 30, 1929	Total Excavation to November 30, 1929
East Heading	143 ft.	3,700 ft.	3,843 ft.
West Heading	135 ft.	4,220 ft.	4,355 ft.
Total	278 ft.	7,920 ft.	8,198 ft.

Weekly advances during January, when two single shifts were used, averaged about 42 feet in each heading. After starting two double shifts in February these weekly advances increased to about 88 feet in each heading until the middle of October when water was encountered in the east heading, cutting down the progress in this heading very materially.

The tunnel is being driven with a heading and bench method, the bench being about six feet long and six feet high.

The force employed by the contractor has averaged 79 men, two shifts being employed.

The principal items of plant at Shaft 8 were as follows:

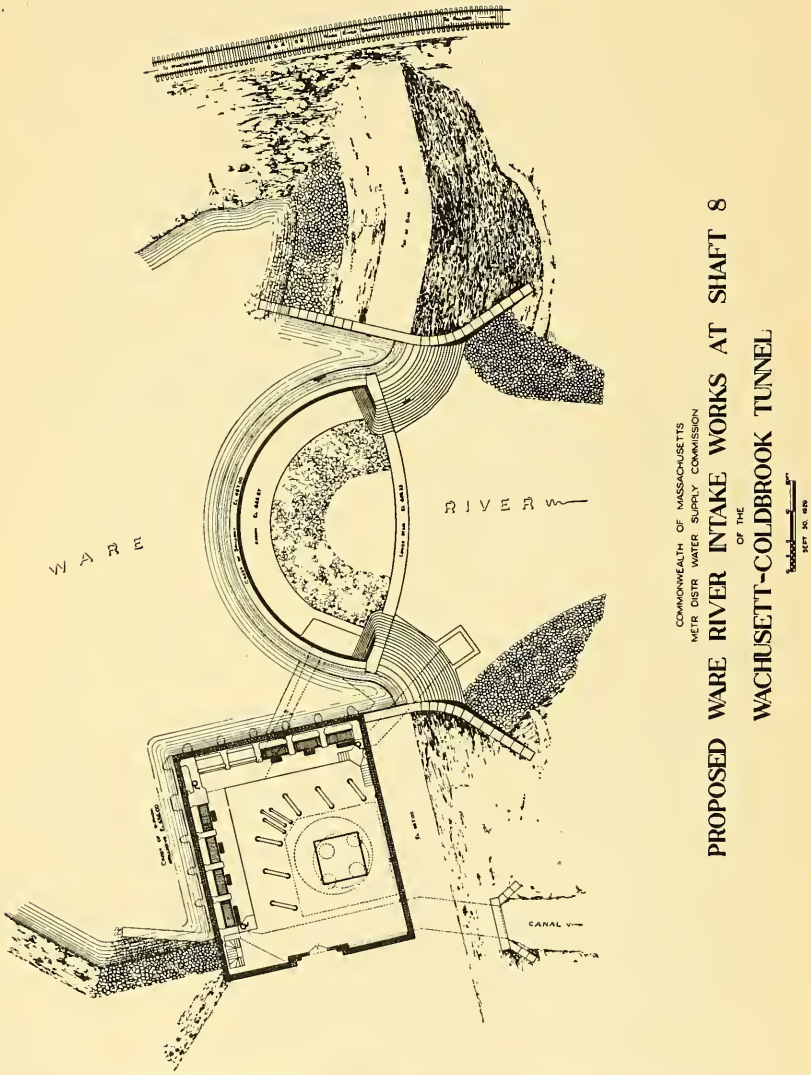
3 Air Compressors, each of 750 cu. ft. per min. capacity, run by 100 H.P. motors.
1 14′0″ x 4′6″ air receiver tank.
1 Blower, rated at 4,100 cu. ft. of free air per min. run by 60 H.P. motor.
1 Mine Hoist.
1 Gasoline driven locomotive.
4 Mucking machines.
10 Pumps, the largest of which has a rated capacity of 1,000 gals. per min. under 100-ft. head run by 40 H.P. motor.
Cars, drill equipment, machine shop equipment, etc.

The total work done and materials furnished to date under the principal items of Contract 17 were as follows:

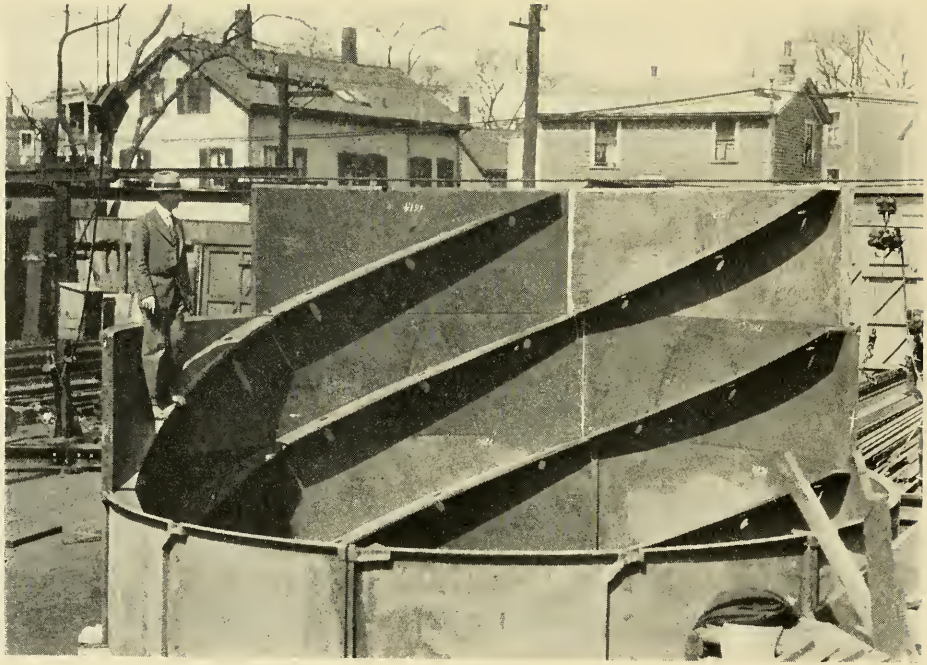
	Shaft 5	Shaft 6	Shaft 7	Shaft 8
Rock excavation in shafts, and in tunnel within 50′ of shafts (cu. yds.)	–	–	–	4,664
Excavation in tunnel except within 50′ of shafts (cu. yds.)	70,515	55,467	52,310	54,811
Shaft and tunnel drainage (lin. ft.)	7,648	7,419	6,001	5,443
Forms for preliminary concrete lining, Shaft 8, (lin. ft.)	–	–	–	217
Concrete masonry in shafts (cu. yds.)	9	–	–	715
Concrete masonry not in shafts or tunnel (cu. yds.)	–	–	–	300
Permanent timbering in tunnel (M ft. B. M.)	–	–	1.84	–
Temporary timbering in tunnel (M ft. B. M.)	3.44	–	–	–
Portland Cement (bbls.)	12	–	–	1,277
Earth excavation (cu. yds.)	–	–	–	570
Rock excavation except in shafts or tunnel (cu. yds.)	–	–	–	760
The contractor's total force averaged (men)	90	84	67	79

Coldbrook-Swift Tunnel Division — Hardwick Office

The Coldbrook-Swift Tunnel Division continued in charge of the field work in connection with the proposed Coldbrook-Swift Tunnel Extension to the Swift River and of the construction at Shaft 8 of the Wachusett-Coldbrook Tunnel included in Contract 17, and previously described. It also has charge of the construction of the low diversion dam and the Ware River Intake Works at Shaft 8, included in Contract 19.



Plan of Proposed Ware River Intake Works at Shaft 8.



Contract 18. — Cast iron lining plates for Ware River Intake, Shaft 8, assembled at the Foundry.

Office Work

Maps were made of properties acquired by the Commission in the vicinity of the village of Coldbrook and along the Ware River above Coldbrook. Ownership of real estate along the line of the proposed Coldbrook-Swift Tunnel was determined and maps were made of property along the tunnel line.

Contour maps were made of various ponds in the Ware River Watershed. Capacity curves were made up for a number of these ponds.

Rain gage stands and thermometer shelters were made for use at the Enfield and White Valley meteorological stations, which stations were put in use on June first. Calculation and tabulation of current meter measurements for ice effect on the controls at the Ware River gaging stations were carried on throughout the winter.

Field Work

Surveys were made of various ponds, mainly in the Ware River Watershed. Investigations were made of the location and condition of wells and springs forming the water supply of the White Valley tenements of the Commission.

A rain gage and a maximum and minimum thermometer were set on June 1, and records kept throughout the year. This office also cooperated with the Boston Office in Hydrographic studies hereinbefore described.

Progress of Contracts

The construction work on the Wachusett-Coldbrook Tunnel from Shaft 8 was supervised from the Hardwick Office and is hereinbefore described.

Contract 18. — Contract 18, for furnishing iron castings for the Ware River Intake Works on the Wachusett-Coldbrook Tunnel in the town of Barre, was executed on January 14, with Barbour Stockwell Company.

These castings include 300 shaft lining plates, 4 nozzle castings to direct the discharge from the Dow disc valves against the lining plates, and 4 base castings to support the valves.

The value of work included in contract estimate to November 10, the date of the latest estimate, was $14,488.72, of which 90% was approved for payment.

The materials furnished under the principal items of Contract 18 were as follows:

Shaft lining plates	191.7 tons
Nozzle castings	24.6 tons
Base castings	3.1 tons

Contract 19. — Contract 19, for constructing the low diversion dam and the substructure of the building for the Ware River Intake Works at Shaft 8 of the Wachusett-Coldbrook Tunnel in the town of Barre, was executed on July 23, with J. W. Bishop Company of Worcester, Mass.

Work started immediately on a road for access to the site. The old mill canal was cleared, using a small caterpillar crane, to take care of the low flow of the river. The channel of the river was cleared with a steam shovel from the dam site to about 200 feet downstream, and two wooden cofferdams were built across the river upstream and downstream from the site, connected by a wooden flume about 12 feet wide and 6 feet deep to carry the flow in excess of the canal capacity. A temporary bridge was built across the Ware River just below the work, and a temporary railroad siding on the south bank from the Boston and Albany Railroad track. Three derricks cover the whole work as well as the siding.

Concreting started about the middle of September. The by-pass sluiceway and Venturi meter for discharging the normal low river flow and piers for five spillway openings in the south side and one in the north side of the intake building substructure were constructed. Grout holes about 20 feet deep and 20 feet apart were drilled along the line of the dam and grouted. Only two holes took any appreciable amount of grout, about 30 bags of cement each. Concrete was proportioned with a weighing aggremeter and was mixed by a three-quarter cubic yard cube mixer.

Stone facing is of Fitchburg granite. The first stone was set on the south abutment on October 25. Stone setting has been carried on since that date.

Refill in the dam and south abutment excavation was started about October 26. This refill was made by puddling the clayey material from the south abutment

excavation, except within the lines of the dike back of the abutment where tamped topsoil was used for impervious fill, and tamped soil and gravel for the remainder.

The culvert under the Boston & Albany Railroad was started about September 23. A pile trestle was put in to support the rails after which excavation was started behind bracing. The concreting for this culvert was finished on October 11, after which the old culvert and the brook bed were filled with earth.

The value of work included in contract estimates to November 15, the date of the latest estimate, was $105,993.41, of which 90% was approved for payment.

The principal items of plant equipment used on Contract 19 were as follows:

2 Derricks with guyed mast and boom
1 Stiff leg derrick
1 ¾-cubic yard concrete mixer
1 Concrete aggremeter, bins and scales
1 Steel concrete chuting tower.

The contractor's force averaged 55 men. The maximum force during any one week was 74 men for the week ending October 12.

Swift River Reservoir Division — Enfield Office

The Swift River Reservoir Division continued in charge of the field work in the Swift River Valley in connection with the proposed Swift River Reservoir.

The major engineering activities of this division were the continuance of topographic surveys of the proposed reservoir basin, general surveys of real estate required for reservoir purposes, and preparation of maps of all surveys.

Topography. — During the year 5,915 acres of topography within and adjacent to the proposed reservoir were surveyed making the total to date 22,775 acres or 35.59 square miles. During the year 6,560 acres of topography were mapped, making the total mapped to date 22,600 acres. Of this total, tracings have been made covering 17,365 acres. Field and office studies were made of possible power transmission lines for supplying power during the construction of the reservoir and appurtenances. Miscellaneous preliminary studies and maps were made to furnish data required by the designing division. 292 acres were surveyed for preliminary studies of highway relocation.

Real Estate. — Property described in application by owners for sale of real estate was located and sketches showing the approximate location made. Property purchased by the Commission during the year, as the deeds were received in the Enfield Office, was plotted on the general property map with a scale 1 inch = 1,000 feet. Comprehensive real estate surveys were continued throughout the year to ultimately include the entire area required for reservoir purposes. The work included analyses of old deeds and suggested descriptions for deed conveyances.

The real estate surveys during the year covered 16,585 acres, making a total to date of 52,500 acres or 82.03 square miles. Of this total, 50,775 acres have been plotted at a scale of 1 inch = 200 feet.

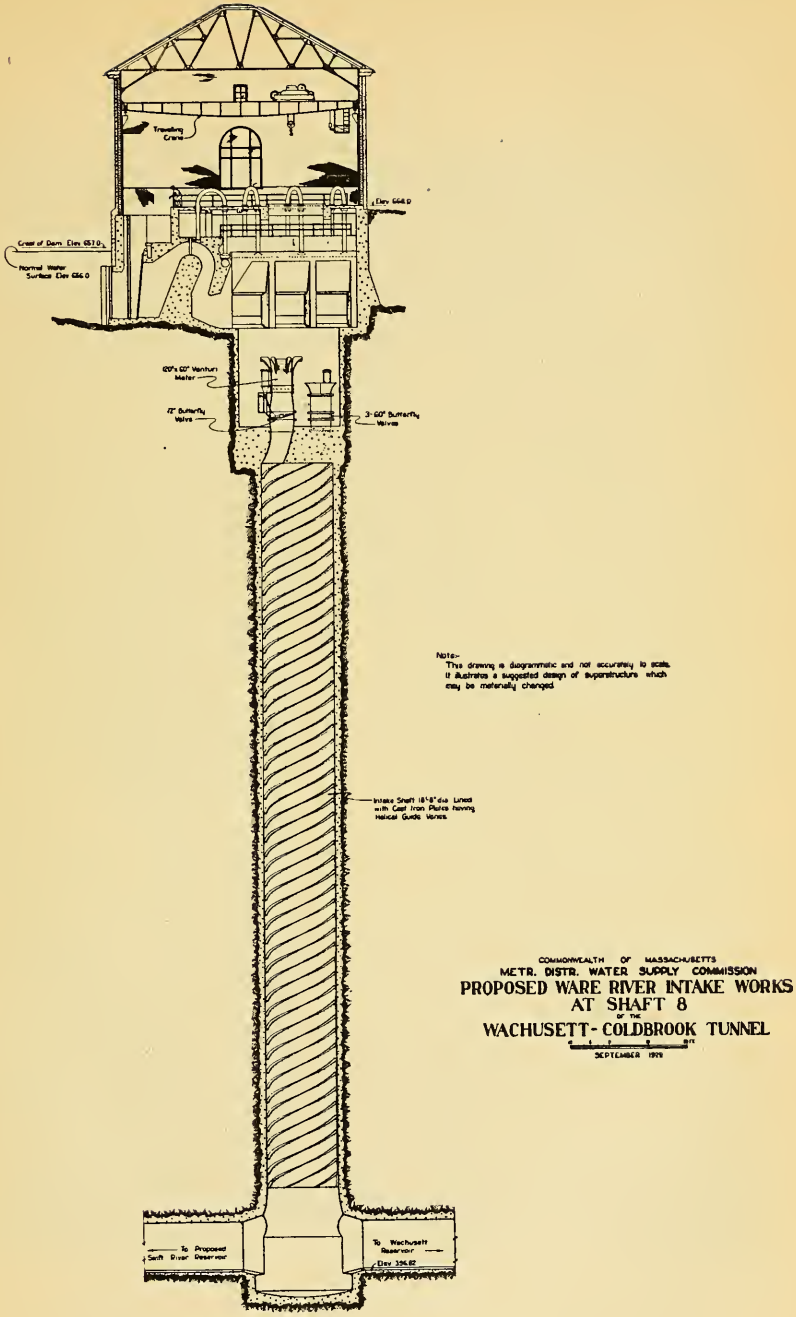
Photography. — Photographs of all buildings which have been listed for purchase were taken and record prints made. During the year 185 photographs of buildings, cemetery lots, and other special features in the Swift River Valley were taken. The photographic facilities of this division were also utilized by other divisions to show progress on construction contracts.

Cemeteries. — A card index was made embracing data relative to each marked interment in cemeteries within the reservoir area. A similar index of cemetery lots was started to include data relative to lot ownership. Relationship of the deceased one to another together with relationship of living interested parties was determined as required.

There has been no general removal of bodies from within the proposed reservoir and such removals as have been made were at the request of interested parties. During the year 212 bodies were removed from 72½ lots in various cemeteries in the area to be affected by the reservoir, together with 81 headstones and 34 monuments, making a total removed to date of 252 bodies, 99 headstones, and 41 monuments.

Soil Testing. — In anticipation of the necessity for the selection of proper materials for embankment fill in the proposed dam and dike, studies were made of recent

Contract 19. — Ware River Diversion Dam, Substructure of Intake Works and headframe of Shaft 8 in background.



Plan of Proposed Ware River Intake Works at Shaft 8.

developments in soil testing methods with particular reference to the permeability of soils such as may be encountered in the Swift River Valley. Through the courtesy of the Massachusetts Institute of Technology, one assistant of this division has spent some time in the Institute Soil Mechanics Laboratory studying various methods and equipment for the testing of the permeability of fine soils.

A laboratory located in the office basement was partially equipped to test the quality of soils available for construction purposes. Numerous samples of top soil were collected from the vicinity of the dam site for testing.

Fire Protection. — The fire fighting equipment housed at Enfield and consisting of a truck, fire pump and general tools, was kept in proper shape for immediate use. Six assistant engineers of this division were reappointed as deputy forest wardens in each of the towns affected by the reservoir.

Because of the extremely dry summer and the consequent drying up of streams which resulted in possible long carries for water, an extra 2,000 feet of one-inch hose was added to the equipment, making a total of 4,500 feet available.

The equipment and personnel responded during the year to calls for assistance at 27 forest fires which burned over a total area of 148 acres. The apparatus also responded to fires in 11 buildings in the valley.

Reforestation. — In the spring 2,000 white pine and 4,000 red pine transplants were received from the State Forest Nursery at Amherst and planted on five acres of land of the Commission in the town of Dana outside the flow line of the proposed reservoir. The young pine survived the summer in good condition.

Blister Rust Control. — In cooperation with the State Department of Agriculture's Bureau of Plant Industry, labor was supplied by this office for the eradication of currant and gooseberry bushes for the control of pine blister rust in that portion of the Swift River Valley above the proposed reservoir flow line. Transportation and supervision were supplied by the Bureau of Plant Industry. The area covered in the cruises for eradication was about 8,300 acres in six towns and 13,056 bushes were destroyed.

Contract 23. — Contract 23 for making borings in the towns of Belchertown, Enfield, Ware, Greenwich and Hardwick was executed on November 5, with Sprague and Henwood, Inc., of Scranton, Pennsylvania. No estimates for payment were made before November 30. The work was confined to explorations in the vicinity of the proposed tunnel portal in the town of Greenwich.

Geologic al Data

Chapter 321, Acts of 1927, provides that the Commission shall collect and publish in its reports such information as to the geology of the region in which any of the work which it is authorized to construct may be located as may be of value in connection with the geological history of the State. Such information, in preliminary form, has been published in the annual reports for the years ending November 30, 1927 and 1928. The geological data have been assembled by Frank E. Fahlquist, Assistant Engineer, under the supervision of Charles P. Berkey, Consulting Geologist.

To date an aggregate length of about 65,000 feet or approximately 87 per cent of the total length of tunnel now under contract has been excavated, and the excavation between Shafts 6 and 7 in the Town of Rutland has been completed.

The method used in obtaining and coordinating geological information is as follows:

A continuous geologic plan and profile of the tunnel excavations on a scale of 20 feet equals 1 inch, was adopted for recording the different geological phenomena observed. All rock types together with their structural features and mineralogical habit have been plotted directly on this profile together with descriptive and explanatory notes. A record is thus being kept of the geological conditions and rock structure including the measurement of each important joint or fracture for location, strike and dip, and a notation of direction and amount of movement.

Specimens have been taken at twenty-five foot intervals throughout the tunnel and, in addition, suites of specimens representing unusual conditions have been collected when it seemed advisable. These specimens, properly labelled as to location, are housed in cases at present in the Holden Office where they are readily accessible for reference. Numerous rock thin sections have been made for more

Paxton Schist in Tunnel, Shaft 4, showing the distinctly banded and laminated appearance, and presence of large and small lens-shaped pegmatite bodies.

detailed study under the microscope. Points of special interest have been photographed.

Work on the several formations within the tunnel area has been extended, as time permitted, into the Worcester basin in an attempt to establish a definite age and structural relation with the Worcester Phyllite recognized by previous workers as of Carboniferous Age.

Cooperation has been given to several geologists who desired to take advantage of the unusual opportunity afforded to study the tunnel excavations at first hand. In a few cases this has led to further investigation of certain specific problems, which still continues.

General Summary of Observations. — No new formations, other than those previously reported, have been discovered in any of the tunnels, but new information as to their distribution has been obtained.

The phyllitic quartzite, in the stretch of tunnel excavated west from Shaft 1, has continued about the same in its mineralogy and structural habit. It is not possible, at this time, to state the nature of the contact between this formation and the Fitchburg Granite to the West, and the exposure of the contact between the two should reveal much valuable geologic information and clarify a few of the points at present undetermined.

The Fitchburg Granite of Shaft 2. — The character of the rock in the tunnel at Shaft 2, known and mapped in the preliminary geological map of Massachusetts as the Fitchburg Granite, has likewise continued in its behavior and occurrence as reported previously. The formation contains extensive bodies of schist, which are now recognized as remnants of the former roof or cover that existed before the invasion of the granite. This cover of schist appears to have been soaked in place by granitic juices which resulted in the partial and sometimes complete replacement of the original schist. Wherever the rock appears as a granite it almost always has a distinct foliation, which is parallel or closely parallel to the structure of the nearby schist bodies. This fact is clearly recognized from the plotted observations of 9,000 feet of geologic profile taken in this section. It appears, then, that it will be quite possible to piece together the structural information in the granite belt and determine partially at least the attitude and behavior of the original schist during deformation.

Pegmatite, in its simplest habit, occurs extensively both in the schist areas and the granite areas, but seldom in bodies of sharp outline. They usually are of irregular shape with transition zones between this type and the surrounding rock. In the more schistose zones the pegmatite frequently occurs in the form of feldspar bunches and augen, and generally contains quartz, biotite, and feldspar, with only occasional muscovite and black tourmaline. No other minerals, such as sometimes occur in pegmatites, have been found.

The widespread general occurrence of these three types of rock suggests an interesting problem as to origin; whether formed, as most granites are believed to have been, by crystallization of a granitic liquid or magma, or instead by intense granitization of the overlying schist by soaking and replacement.

The structure throughout is moderately flat, with few zones where the structure is steep for short distances and sometimes even vertical. These zones of strong structure, which are often highly injected, may have special significance in the general structural problem of the area.

The Paxton and Brimfield Schists of the Central Belt. — Excavations in the central belt of schists between Shaft 3 and 8 has revealed one new fact in the stratigraphic distribution of the Paxton and Brimfield schists of the preliminary geological map of Massachusetts. These two types are now believed to be simply different lithologic members of the same formation, since the Brimfield Schist type lies conformably both above and below the Paxton Schist. The Paxton Schist type appears to be the more extensive member as exposed in the tunnel where it extends from a point about 4,500 feet west of Shaft 5 to a point about 500 feet east of Shaft 4. Throughout this section of approximately 17,000 feet it maintains a low easterly dip. It occurs again in the tunnel at Shaft 6 extending at least 6,800 feet from a point about 2,000 feet west of the shaft to the east heading and indicating that a short stretch of Brimfield Schist type separates it from the Paxton of Shaft 5. It next occurs in the tunnel east of Shaft 7 where it is exposed for about 3,000 feet, and maintains a gentle easterly dip.

The Brimfield Schist type extends throughout the tunnels between Shafts 7 and 8 and westerly, forming a rather broad and low anticlinal fold. It appears also, that it would extend from the conformable contact east of Shaft 4, through Shaft 3 and make a contact with the Fitchburg Granite at some point east of Shaft 3, not yet revealed by tunnel excavations. Throughout the portion of the section excavated this rock maintains a rather low easterly dip. There is also a short length of about 2,000 feet exposed in the tunnel west of Shaft 6, where it also maintains a moderate easterly dip, passing under the Paxton Schist. This is apparently continuous with the Brimfield type in the tunnel west of Shaft 5.

The Paxton Schist type is the most uniform of the formations encountered. The rock is essentially a medium grained quartz-mica schist with variable amounts of feldspar, often in quantities great enough to make the rock a feldspathic biotite schist. It is distinctly banded and laminated, this effect being produced by variations in the proportions of the main constituents, more especially by the greater concentration of biotite mica in bands. Yet another cause of banded appearance is the occurrence of narrow somewhat discontinuous greenish streaks and layers or lenses, the dominant composition of which is feldspar, quartz, red garnet and green diopside. The presence of the garnet and diopside suggests that the original sediment was an impure feldspathic sandstone containing limy layers.

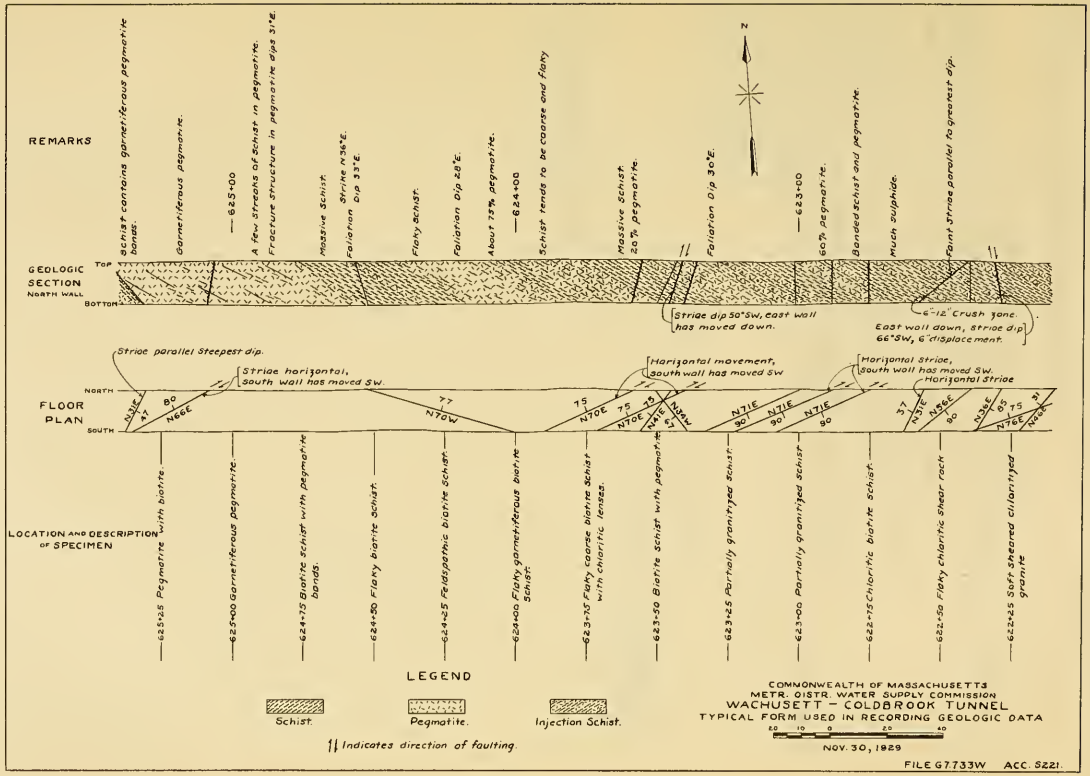
A distinctive feature of this formation is the presence of innumerable lens shaped bodies of pegmatite made up chiefly of feldspar with relatively small amounts of quartz. These bodies, varying from a fraction of an inch to several feet in length, appear to have both replaced and displaced the surrounding schist, and thus present a problem as to origin and method of development.

The Brimfield Schist type, as it occurs in the tunnel excavations, is a rock of great variety in petrographic character and geologic behavior. It is made up of five rock types, (1) a dark brown flaky biotite schist with very little quartz or feldspar but commonly containing garnet, (2) a highly quartzose biotite schist or a biotite meta-quartzite, (3) a massive feldspathic biotite schist sometimes containing garnet, (4) a gray gneissoid granite and (5) pegmatite. These several types, excepting those of igneous origin, occur in intercalated layers or beds ranging from a few inches to many feet in thickness. This condition had been recognized before and on this account the name of Paxton Mixed Injection Schist was given to the formation, evidence of igneous soaking or injection in some form being present almost everywhere. The pegmatites occur as small feldspar bunches, as thin lenses and bands in the schist producing a banded or ribbon structure, as large lenses in the schist, and as still larger bodies, some of which are sill-like in sections and others of which are very irregular with embayed contacts showing partial replacements of the schist. The granite generally occurs in sill form with sharp margins parallel to the schist structure, but also as irregular masses with margins that are gradational into the surrounding schist. Throughout the formation, especially in zones of crushing and movement, there is considerable development of chlorite and introduction of carbonate and sulphide.

Deformation. — The lack of faulting to any great extent in the tunnels so far excavated in the broad schist belt of the Paxton and Brimfield types is a surprising fact. It is true that evidence of movement has been noted on many of the joint surfaces but the displacements are measured in terms of inches. In most cases the greater part of the movement has been in a horizontal direction. Slips and shear zones have been noted where the greatest component of displacement is vertical.

Several major problems have been recognized and are being studied. Among them are the following:

1. Grouping of the many rock types and varieties into formational units that have a sound genetic basis and that can be defined.
2. The character and thicknesses of the original sediments, and the method of metamorphism into the schists now forming the central belt.
3. Structural relation of the schists in the central part of the tunnel area one to another and to the Oakdale Quartzite and Worcester Phyllite of the Worcester Basin.
4. The geologic age of these formations.


REMARKS
Schist contains garnetiferous pegmatite bands.
Garnetiferous pegmatite.
625+00
A few streaks of schist in pegmatite.
Fracture structure in pegmatite dips 31°E.
Massive Schist.
Foliation Strike N36°E. Dip 33°E.
Flaky schist.
Foliation Dip 28°E.
About 75% pegmatite.
624+00
Schist tends to be coarse and flaky
Massive Schist. 20% pegmatite.
Foliation Dip 30°E.
623+00
60% pegmatite.
Banded schist and pegmatite.
Much sulphide.
Faint Striae parallel to greatest dip.
GEOLOGIC SECTION
NORTH WALL
TOP
BOTTOM
Striae dip 50°SW, east wall has moved down.
6"-12" Crush zone.
East wall down, Striae dip 66°SW, 6" displacement.
FLOOR PLAN
NORTH
SOUTH
Striae parallel Steepest dip.
Striae horizontal, south wall has moved SW.
Horizontal movement, south wall has moved SW
Horizontal Striae, south wall has moved SW.
Horizontal Striae
N31E 47 80 N66E
77 N70W
75 N70E 75 N70E 75 N41E 67 N34W
N71E 90 N71E 90 N71E 90
37 N31E 90 N56E 90 N36E 85 75 N76E 31 N46E
LOCATION AND DESCRIPTION OF SPECIMEN
625+25 Pegmatite with biotite.
625+00 Garnetiferous pegmatite.
624+75 Biotite schist with pegmatite bands.
624+50 Flaky biotite schist.
624+25 Feldspathic biotite schist.
624+00 Flaky garnetiferous biotite schist.
623+75 Flaky coarse biotite schist with chloritic lenses.
623+50 Biotite schist with pegmatite.
623+25 Partially granitized schist.
623+00 Partially granitized schist.
622+75 Chloritic biotite schist.
622+50 Flaky chloritic shear rock.
622+25 Soft sheared chloritized granite
LEGEND
Schist.
Pegmatite.
Injection Schist.
Indicates direction of faulting.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
WACHUSETT - COLDBROOK TUNNEL
TYPICAL FORM USED IN RECORDING GEOLOGIC DATA
20 10 0 20 40
NOV. 30, 1929
FILE G7.733W ACC. S221.

5. The relation of schist bodies in the granite of the eastern section to the central belt of schist and likewise to the Worcester basin sediments.

6. The mode of injection into the schists and the relative amounts of replacement and displacement.

7. The mode of development of the granite in the eastern section and the relative amount of true intrusive granite belonging to the formations as they now exist.

8. Nature of later deformation affecting the region as shown by jointing, shearing and faulting.

9. The petrology of the different formations.

List of Drawings and Tables

For General Plan of Metropolitan Water Supply and Profile of Wachusett-Coldbrook Tunnel, see Second Annual Report.

The following tabulations are appended to this report:

Monthly Progress — Real Estate Negotiations for Swift River Reservoir.
Location of Real Estate Acquired for the Swift River Reservoir.
Real Estate Takings.
Status of Contracts Completed Prior to Nov. 30, 1928.
Status of Contracts in Force between Nov. 30, 1928, and Nov. 30, 1929.
Total Value of Work Accomplished under Contracts in Progress During Year Ending Nov. 30, 1929 — Shown Monthly.
Canvass of Bids, Contract 18.
Canvass of Bids, Contract 19.
Canvass of Bids, Contract 22.
Canvass of Bids, Contract 23.

Respectfully submitted,

FRANK E. WINSOR,
Chief Engineer.

24 School Street, Boston, Mass.
December 27, 1929.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
Administration (Commissioners' Office):		
Salaries, Commissioners	$10,500.00	$35,112.80
Salaries, Clerical	10,591.64	28,320.67
General Legal Expense	0.00	1,377.30
Furniture and Fixtures	79.53	1,894.31
Rent and Upkeep	3,101.05	6,062.76
Automobile Purchase	595.00	1,404.00
Automobile Maintenance	290.54	959.02
Miscellaneous Expense (undistributed)	667.97	5,400.77
Advertising	1,405.33	2,153.98
Printing and Blueprinting	993.74	2,115.59
Stationery and Office Supplies	295.26	585.21
Postage	116.00	249.69
Total Administration	$28,636.06	$85,636.10
Engineering, Headquarters Office:		
Salaries, Engineering	$86,719.81	$233,154.91
Salaries, Clerical	9,504.31	26,820.11
General Consultant Expense	16,047.89	42,545.41
General Legal Expense	244.69	244.69
Furniture and Fixtures	343.91	10,751.73
Laboratory Equipment	130.28	1,556.46
Laboratory Supplies	562.99	1,932.49
Rental of Equipment	1,996.76	2,861.76
Engineering Instruments	22.92	63.54
Rent and Upkeep of Boston Office	9,521.71	31,101.33
Rent and Upkeep of Springfield Laboratory	1,769.15	2,346.03
Automobile Purchase	595.00	2,090.70
Automobile Maintenance	818.69	1,625.99
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	3,231.83	11,521.11
Printing and Blueprinting	1,719.86	4,107.57
Stationery and Office Supplies	565.86	1,473.15
Postage	217.26	422.33
Total Engineering, Headquarters Office	$134,013.62	$376,923.94
Unassigned:		
Unassigned Supplies and Equipment	-$61.90	$1,006.91
Total Unassigned	-$61.90	$1,006.91
Total General Overhead	$162,587.78	$463,566.95

Distribution of General Overhead

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
Administration:		
Wachusett-Coldbrook Tunnel Division	$13,836.87	$34,597.08
Coldbrook-Swift Tunnel Division	2,062.05	5,431.57
Swift River Reservoir Division	12,727.55	36,952.73
Southern Sudbury Emergency Supply	9.59	8,654.72
Total Administration	$28,636.06	$85,636.10
Engineering, Headquarters Office:		
Wachusett-Coldbrook Tunnel Division	$53,410.85	$139,356.71
Coldbrook-Swift Tunnel Division	14,261.12	26,597.68
Swift River Reservoir Division	66,035.80	177,666.28
Southern Sudbury Emergency Supply	305.85	33,303.27
Total Engineering, Headquarters Office	$134,013.62	$376,923.94

Wachusett-Coldbrook Tunnel Division

General Overhead:		
Administration	$13,836.87	$34,597.08
Engineering	53,410.85	139,356.71
Total General Overhead	$67,247.72	$173,953.79
Engineering:		
Salaries, Engineering and Clerical	$82,585.10	$195,443.85
Consultant Expense	1,893.19	3,521.25
Furniture and Fixtures	416.68	1,487.31
Engineering Instruments	245.94	7,386.94
Rent and Upkeep	2,163.54	6,091.18
Automobile Purchase	2,303.25	6,818.21
Automobile Maintenance	2,262.40	7,368.39
Contracts for Investigations and Surveys	0.00	16,075.11
Miscellaneous Expense (undistributed)	1,152.54	4,140.06
Advertising	1.83	6.05
Printing and Blueprinting	140.38	532.39
Stationery and Office Supplies	279.70	1,618.60
Postage	36.64	211.99
Total Engineering	$93,481.19	$250,701.33
Real Estate (General Construction):		
Legal and Expert Expense	$488.56	$4,001.02
Consultant Expense	0.00	394.40
Labor	−110.00	906.55
Miscellaneous Expense	0.00	241.24
Purchases and Settlements	10,557.25	106,939.71
Taxes	1,280.86	2,037.98
Maintenance of Real Estate	218.39	218.39
Police Protection, Labor	5.00	15.00
Special Agents, Salaries	2,310.00	3,393.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	0.00	595.50
Automobile Maintenance	608.12	729.81
Miscellaneous Expense (undistributed)	362.61	438.96
Printing	0.00	7.89
Postage	0.36	0.36
Total Real Estate	$15,721.15	$120,037.48

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
WARE WATERSHED PROTECTION:		
Salaries, Engineering	$2,729.52	$2,729.52
Legal and Expert Expense	1,194.49	3,918.92
Consultant Expense	0.00	763.70
Labor	780.00	2,045.00
Miscellaneous Expense	142.40	188.24
Printing and Blueprinting	22.04	22.04
Purchases and Settlements	125,857.71	420,346.37
Taxes	−1,952.26	3,008.66
Total Ware Watershed Protection	$128,773.90	$433,022.45
WARE DIVERSION DAMAGES:		
Salaries, Engineering and Clerical	$12,916.73	$12,916.73
Consultant Expense	1,490.78	1,943.17
Labor	19.62	19.62
Miscellaneous Expense (undistributed)	1,229.85	2,824.88
Printing and Blueprinting	42.56	67.55
Postage	0.75	0.75
Engineering Instruments	45.08	45.08
Laboratory Equipment	37.14	37.14
Laboratory Supplies	27.88	27.88
Rental of Equipment	36.25	36.25
Contracts for Investigations and Surveys	0.00	63.27
Total Ware Diversion Damages	$15,846.64	$17,982.32
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 4, Sinking Shaft 5 and driving 1,367 linear feet of tunnel	$0.00	$290,581.99
Contract No. 8, Sinking Shafts 6 and 7 and driving 3,062.2 linear feet of tunnel	0.00	456,784.26
Contract No. 10, Construction and maintenance of Transmission Line	6,819.87	102,584.96
Contract No. 12, Sinking Shafts 2, 3 and 4 and driving 3,809.6 linear feet of tunnel	0.00	632,727.44
Contract No. 14, Construction of East Portion of Wachusett-Coldbrook Tunnel and Shaft 1	1,407,510.58	1,649,160.71
Contract No. 17, Construction of West Portion of Wachusett-Coldbrook Tunnel and Shaft 8	1,949,794.19	2,392,237.47
Contract No. 18, Furnishing Iron Castings for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	13,039.85	13,039.85
Contract No. 19, Construction of Dam, and Substructure of Intake Building for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	95,394.07	95,394.07
Total Contracts	$3,472,558.56	$5,632,510.75
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$9,809.96	$9,901.84
Temporary Equipment	283.00	5,033.10
Miscellaneous Expense	987.99	1,876.01
Investigations and Surveys	0.00	898.34
Total	$11,080.95	$17,709.29
Total Wachusett-Coldbrook Tunnel Division	$3,804,710.11	$6,645,917.41

Coldbrook-Swift Tunnel Division

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
General Overhead:		
Administration	$2,062.05	$5,431.57
Engineering	14,261.12	26,597.68
Total General Overhead	$16,323.17	$32,029.25
Engineering:		
Salaries, Engineering and Clerical	$4,547.46	$32,845.15
Furniture and Fixtures	200.46	425.95
Engineering Instruments	70.48	3,355.25
Rent and Upkeep	1,151.24	2,890.10
Automobile Purchase	2,331.75	4,311.75
Automobile Maintenance	3,115.89	5,479.04
Contracts for Investigation and Surveys	0.00	12,831.65
Materials of Construction	0.00	2.25
Miscellaneous Expense (undistributed)	651.49	2,499.22
Printing and Blueprinting	95.72	208.81
Stationery and Office Supplies	242.81	838.47
Postage	45.19	139.12
Total Engineering	$12,452.49	$65,826.76
Real Estate:		
Legal and Expert Expense	$1,157.51	$1,571.33
Miscellaneous Expense (undistributed)	0.00	12.30
Printing and Blueprinting	0.67	0.67
Purchases and Settlements	–236.30	0.00
Taxes	–867.47	0.00
Fire Protection Equipment	0.00	17.06
Total Real Estate	$54.41	$1,601.36
Permanent Construction — Except Construction Contracts:		
Installed Equipment	$0.00	$91.87
Total	$0.00	$91.87
Total Coldbrook-Swift Tunnel Division	$28,830.07	$99,549.24

Swift River Reservoir Division

General Overhead:		
Administration	$12,727.55	$36,952.73
Engineering	66,035.80	177,666.28
Total General Overhead	$78,763.35	$214,619.01
Engineering:		
Salaries, Engineering and Clerical	$63,746.77	$192,228.84
Labor	871.94	871.94
Furniture and Fixtures	1,321.00	2,488.17
Engineering Instruments	39.98	5,435.89
Rent and Upkeep	1,055.73	1,664.90
Automobile Purchase	2,411.75	8,468.71
Automobile Maintenance	2,445.05	7,616.53
Special Experiments	119.88	119.88
Contracts for Investigations and Surveys	0.00	35,448.91
Rental of Equipment	0.50	0.50

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
ENGINEERING — *Concluded.*		
Office Buildings	$3,092.38	$4,015.61
Miscellaneous Expense (undistributed)	339.95	2,489.69
Printing and Blueprinting	231.62	757.66
Stationery and Office Supplies	375.15	2,748.52
Postage	61.74	265.10
Total Engineering	$76,113.44	$264,620.85
REAL ESTATE:		
Legal and Expert Expense	$22,998.39	$77,692.00
Labor	0.00	56.10
Furniture and Fixtures	15.68	15.68
Miscellaneous Expense (undistributed)	639.19	1,402.44
Advertising	92.97	112.26
Printing and Blueprinting	49.80	49.80
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	1,138,916.48	3,241,937.46
Taxes	20,176.69	34,528.20
Maintenance of Real Estate	529.82	529.82
Fire Protection Equipment	686.81	2,504.24
Automobile Purchase	0.00	200.00
Automobile Maintenance	53.74	90.35
Miscellaneous Expense	41.25	55.61
Special Agents, Salaries	2,310.00	3,741.33
Equipment	0.00	118.33
Automobile Purchase	0.00	609.96
Automobile Maintenance	559.45	833.73
Miscellaneous Expense (undistributed)	169.22	335.13
Printing and Blueprinting	0.00	41.60
Postage	1.00	2.42
Stationery and Office Supplies	3.52	3.52
Renting Agents, Salaries	2,500.00	4,655.43
Furniture and Fixtures	0.00	29.29
Miscellaneous Expense	92.43	106.47
Payments to Towns	2,000 00	2,000 00
Total Real Estate	$1,191,836.44	$3,371,651.62
SWIFT RESERVOIR DAMAGES:		
Salaries, Engineering	$14.58	$14.58
Consultant Expense	0.00	921.47
Purchases and Settlements	6,046.00	6,046.00
Miscellaneous Expense	1.90	1.90
Total Swift Reservoir Damages	$6,062.48	$6,983.95
SWIFT DIVERSION DAMAGES:		
Salaries, Engineering	$6,284.86	$9,296.72
Consultant Expense	725.15	2,085.69
Engineering Instruments	529.70	529.70
Laboratory Equipment	19.99	19.99
Automobile Maintenance	0.00	1.25
Contracts for Investigations and Surveys	0.00	569.47
Laboratory Supplies	20.98	20.98
Miscellaneous Expense (undistributed)	716.42	2,781.88
Printing and Blueprinting	46.57	46.57
Total Swift Diversion Damages	$8,343.67	$15,352.25

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
CEMETERIES:		
Salaries, Engineering and Clerical	$1,317.51	$1,317.51
Legal and Expert Expense	25.75	25.75
Labor	1,585.88	2,130.88
Miscellaneous Expense (undistributed)	13.99	65.80
Stationery and Office Supplies	3.51	3.51
Purchases and Settlements	1,320.50	1,876.50
Monuments and Inscriptions	236.55	236.55
Materials	544.16	883.59
Transportation of Bodies	0.00	45.00
Transportation of Monuments	249.00	382.00
Total Cemeteries	$5,296.85	$6,967.09
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$214.78
Total	$0.00	$214.78
Total Swift River Reservoir Division	$1,366,416.23	$3,880,409.55
SOUTHERN SUDBURY EMERGENCY SUPPLY		
GENERAL OVERHEAD:		
Administration	$9.59	$8,654.72
Engineering	305.85	33,303.27
Total General Overhead	$315.44	$41,957.99
ENGINEERING:		
Salaries	$587.49	$33,810.46
Consultant Expense	0.00	3,816.25
Furniture and Fixtures	0.00	30.70
Engineering Instruments	0.00	216.06
Rent and Upkeep	0.00	543.40
Automobile Purchase	0.00	1,919.00
Automobile Maintenance	0.00	1,514.45
Labor	0.00	173.00
Miscellaneous Expense (undistributed):	277.23	1,575.75
Printing and Blueprinting	0.00	215.33
Stationery and Office Supplies	0.00	567.87
Postage	0.00	52.80
Total Engineering	$864.72	$44,435.07
REAL ESTATE:		
Legal and Expert Expense	$360.37	$1,814.24
Consultant Expense	0.00	116.87
Purchases and Settlements	2,825.00	16,488.22
Total Real Estate	$3,185.37	$18,419.33
SOUTHERN SUDBURY DIVERSION DAMAGES:		
Consultant Expense	$0.00	$869.50
Legal and Expert Expense	6.93	212.66
Settlements	550.00	24,550.00
Total Southern Sudbury Diversion Damages	$556.93	$25,632.16

	Year ending Nov. 30, 1929	Total to Nov. 30, 1929
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 5, Cordaville Pipe Line	$0.00	$83,262.86
Contract No. 6, Cordaville Pumping Station	0.00	17,385.04
Contract No. 7, Hopkinton Pipe Line	0.00	134,365.72
Contract No. 11, Ashland Pipe Line	0.00	130,145.35
Contract No. 13, Whitehall Pipe Line	0.00	60,603.17
Contract No. 16, Whitehall Open Channel	0.00	32,695.16
Total Contracts	$0.00	$458,457.30
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.40	$7,960.51
Miscellaneous Expense	9.69	2,758.77
Labor	0.00	1,011.00
Materials of Construction	0.00	207.09
Total	$10.09	$11,937.37
Total Southern Sudbury Emergency Supply	$4,932.55	$600,839.22
SUMMARY		
Wachusett-Coldbrook Tunnel Division	$3,804,710.11	$6,645,917.41
Coldbrook-Swift Tunnel Division	28,830.07	99,549.24
Swift River Reservoir Division	1,366,416.23	3,880,409.55
Southern Sudbury Emergency Supply	4,932.55	600,839.22
Unassigned	-61.90	1,006.91
Grand Total	$5,204,827.06	$11,227,722.33
RECEIPTS FROM RENTS, SALES, ETC.		
Receipts from Sales	$21,680.90	$29,196.57
Receipts from Rents	38,121.32	57,965.33
Miscellaneous Receipts	58.90	110.38
Total Receipts	$59,861.12	$87,272.28

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

MONTHLY PROGRESS – REAL ESTATE NEGOTIATIONS FOR SWIFT RIVER RESERVOIR

DATE	OWNERS' OFFERS TO SELL TO COMMONWEALTH			TITLE VESTED IN COMMONWEALTH (ACRES)	
	NUMBER OF OFFERS	TOTAL AREA (ACRES)	AREA NOT REQUIRED (ACRES)		
1928 December	12	261	120	658	
1929 January	20	481	132	699	
February	11	498	182	999	
March	9	1,289	0	365	
April	29	644	1	627	
May	26	696	237	1,712	
June	34	662	121	1,782	
July	26	416	171	1,226	
August	24	1,563	289	1,140	
September	9	342	37	693	
October	15	682	120	814	
November	11	1,336	186	474	
Total for Year ending Nov. 30, 1929.	226	8,870	1,596	11,189	
Total — Nov. 30, 1928.	1,210	50,119	5,485	23,597	
Total — Nov. 30, 1929.	1,436	58,989	7,081	34,786	

Options Outstanding Nov. 30, 1929 — 4,136. Acres.
Acreage is based upon estimates obtained from deeds or other information and not from surveys.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE SWIFT RIVER RESERVOIR

(TITLE VESTED IN COMMONWEALTH)

TOWNS	TOTAL Nov. 30, 1928. (ACRES)	TOTAL FOR YEAR ENDING Nov. 30, 1929. (ACRES)	TOTAL Nov. 30, 1929. (ACRES)	REMARKS
BELCHERTOWN	1,095	277	1,372	
DANA	2,189	2,871	5,060	
ENFIELD	5,000	686	5,686	
GREENWICH	4,685	1,836	6,521	
HARDWICK	556	1,546	2,102	
NEW SALEM	2,453	1,680	4,133	
PELHAM	1,149	499	1,648	
PETERSHAM	352	68	420	
PRESCOTT	5,730	1,485	7,215	
SHUTESBURY	133	215	348	
WARE	254	26	280	
WENDELL	1	0	1	
TOTALS	23,597	11,189	34,786	

NOTE:- Acreage is based upon estimates obtained from deeds or other information and not from surveys.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

REAL ESTATE TAKINGS

TAKING FOR		TAKING NO.	TOWN	COUNTY	PLAN NO.	DATE OF TAKING	TITLE VESTED IN COMMONWEALTH FEE (Acres)	EASEM'T. (Acres)
Wachusett-Coldbrook Tunnel.		1	Holden	Worcester	T-1 to T-5 incl.	July 22, 1927.	186.01	3.91
			Rutland				1.86	
Wachusett-Coldbrook Tunnel.		2	Rutland	Worcester	T-6 to T-12 incl.	Aug. 26, 1927.	90.90	8.92
			Oakham				6.62	2.00
Wachusett-Coldbrook Tunnel.		3	Oakham	Worcester	T-13	Nov. 11, 1927.	103.58	
			Barre				181.25	0.84
Wachusett-Coldbrook Tunnel.		4	West Boylston	Worcester	T-1A	Aug. 21, 1928.		2.57
			Holden					2.13
Coldbrook-Swift Tunnel.		1	Barre	Worcester	T-14	Sept. 24, 1929.		3.53
							570.22	23.90
Ashland Pipe Line	Sudbury Supply	1	Southborough	Worcester	C-1 & C-2	July 8, 1927.		0.85
			Ashland	Middlesex				4.48
Ashland Pipe Line		2	Ashland	Middlesex	C-8 to C-11 incl.	Nov. 11, 1927.		9.13
			Framingham					1.34
Cordaville Pipe Line		3	Southborough	Worcester	C-3 to C-7 incl.	July 8, 1927.	1.14	8.75
Hopkinton Pipe Line		4	Hopkinton	Middlesex	C-12 to C-14 incl.	Oct. 14, 1927.	64.17	4.47
							65.31	29.02
Indian Brook	Southern Emergency	5	Ashland & Hopkinton	Middlesex	No Plan	Sept. 2, 1927.	Water Diversion.	
Cold Spring Brook		6	Ashland	Middlesex	No Plan	Jan. 6, 1928.		
Sudbury River		7	Southborough, Hopkinton, & Westborough	Wor. & Mid'sex Worcester	No Plan	Jan. 6, 1928.		
City Brook & Whitehall Res.		8	Hopkinton	Middlesex	No Plan	Jan. 6, 1928.		

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED PRIOR TO NOV. 30, 1928

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
1	Borings	Tunnel Line	Ware & Swift	Pennsylvania Drilling Company	Nov. 5, 1926	Nov. 9, 1926	8,260.00	18,641.69	July 15, 1927
2	Borings	Swift Dam & Dike Sites	Swift	Sprague & Henwood, Incorporated	Nov. 5, 1926	Nov. 9, 1926	9,730.00	26,885.83	June 3, 1927
3	Aerial Photographs	Swift River Valley	Swift	Fairchild Aerial Surveys, Incorporated		Nov. 12, 1926	6,955.00	5,997.50	Nov. 2, 1927
4	Shaft 5	Rutland	Ware	James J. Coughlan & Sons, Incorporated	Mar. 25, 1927	Mar. 28, 1927	137,854.80	290,581.99*	June 12, 1928
5	Cordaville Pipe Line	Cordaville to Sudbury Res.	So. Sudbury	Lock Joint Pipe Co.	Apr. 15, 1927	Apr. 15, 1927	78,818.00	83,762.86	Jan. 9, 1928
6	Cordaville Pumping Station	Cordaville	So. Sudbury	F. A. Mazzur Co., Inc.	Apr. 29, 1927	May 2, 1927	16,357.00	17,385.04	May 16, 1928
7	Hopkinton Pipe Line	Hopkinton Res. to Cordaville.	So. Sudbury	Cenedella & Co.	Apr. 29, 1927	May 4, 1927	126,550.00	134,365.72	Dec. 27, 1927
8	Shafts 6 & 7	Rutland	Ware	James J. Coughlan & Sons, Incorporated	May 20, 1927	May 24, 1927	162,125.00	456,784.26*	June 12, 1928
9	Aerial Photographs	Chicopee and Ware Rivers	Ware	Fairchild Aerial Surveys, Incorporated		Mar. 30, 1927	3,090.00	2,560.00	Feb. 17, 1928
11	Ashland Pipe Line	Ashland Res. to Res. No. 2, Gate Ho.	So. Sudbury	Antonio Mogavero	June 3, 1927	June 3, 1927	125,150.00	130,145.35	Sept. 24, 1928
12	Shafts 2, 3 & 4	Holden & Rutland	Ware	Dravo Contracting Company	May 20, 1927	May 24, 1927	259,800.00	632,727.44*	June 12, 1928
13	Whitehall Pipe Line	Whitehall Res. to City Road	So. Sudbury	Portland Contracting Company, Incorporated	July 15, 1927	July 15, 1927	54,963.00	60,603.17	June 12, 1928
15	Electric Power	Cordaville Pumping Station	So. Sudbury	Marlborough Electric Company		Aug. 4, 1927		** 270.09	June 1, 1928
16	Whitehall Open Channel	City Road to Hopkinton Res.	So. Sudbury	Sanders Engineering Company	Sept. 23, 1927	Sept. 23, 1927	36,720.00	32,695.16	July 9, 1928

*This amount includes construction beyond that which was contemplated when proposal was made.
**The Metropolitan District Commission has paid all bills for this contract subsequent to June 1, 1928.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS IN FORCE BETWEEN NOV. 30, 1928 & NOV. 30, 1929

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	BASIS OF AWARD	PAYMENTS TO DATE
10	Transmission Line for Construction of Wachusett-Coldbrook Tunnel.	Tunnel Line	Ware	New England Power Company		Apr. 27, 1927	Maintenance at Cost..... Construction at Cost.....	$17,607.32 *86,439.58
14	East Portion Wachusett-Coldbrook Tunnel.	West Boylston, Holden & Rutland	Ware	West Construction Co., (Assignee)	Nov. 18, 1927	Apr. 30, 1928	$4,074,981.25**	1,649,160.71
17	West Portion Wachusett-Coldbrook Tunnel.	Rutland Oakham & Barre	Ware	West Construction Co., (Assignee)	Nov. 18, 1927	Apr. 30, 1928	4,799,362.50***	2,392,237.47
18	Iron Castings for Ware River Intake Works.	Barre	Ware	Barbour Stockwell Co.	Jan. 4, 1929	Jan. 8, 1929	18,697.83	13,039.85
19	Dam and Substructure of Intake Building.	Barre	Ware	J.W. Bishop Co.	July 16, 1929	July 23, 1929	273,077.00	95,394.07
22	Unwatering Pump at Shaft 1.	West Boylston	Ware	F.A. Mazzur Co., Inc.	Nov. 5, 1929	Nov. 12, 1929	11,975.00	
23	Making Borings.	Belchertown, Ware, Enfield, Greenwich & Hardwick.	Swift	Sprague & Henwood, Inc.	Nov. 5, 1929	Nov. 5, 1929	10,950.00	

*This is the final estimate figure for the, "Construction at Cost," portion of Contract 10.
**Portion of work completed under Contract 12 before Contract 14 was executed reduces this amount by about 7.%
***Portion of work completed under Contracts 4 & 8 before Contract 17 was executed reduces this amount by about 7.%

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TOTAL VALUE OF WORK ACCOMPLISHED UNDER CONTRACTS IN PROGRESS DURING YEAR ENDING NOV. 30, 1929, – SHOWN MONTHLY

CONTRACT NUMBER	10	14	17	18	19	22	23
CONTRACTOR	New England Power Co.	West Const. Co. (Assignee)	West Const. Co. (Assignee)	Barbour Stockwell Co.	J.W. Bishop Co.	F.A. Mazzur Co., Inc.	Sprague & Henwood, Inc.
BASIS OF AWARD	Operation and maintenance at cost	$4,074,981.25 *	$4,799,362.52 **	$18,697.83	$273,077.00	$11,975.00	$10,950.00
DECEMBER 1928	$11,720.93	$388,635.08	$638,221.64				
JANUARY 1929	12,334.07	504,649.14	791,497.38				
FEBRUARY	13,012.87	628,143.34	980,917.76				
MARCH	13,701.74	749,898.40	1,158,224.76				
APRIL	14,363.58	876,825.87	1,354,233.76				
MAY	15,015.47	1,013,557.57	1,556,141.45	$1,610.97			
JUNE	15,769.36	1,167,081.87	1,768,191.45	3,653.54			
JULY	16,496.05	1,300,457.77	1,970,047.45	4,960.57			
AUGUST	17,190.51	1,433,549.20	2,170,144.45	5,907.16	$1,400.81		
SEPTEMBER	17,939.31	1,557,512.24	2,371,256.14	8,855.75	16,602.26		
OCTOBER	18,887.54	1,684,822.84	2,534,884.37	11,221.39	60,706.71		
NOVEMBER	19,563.69	1,832,400.79	2,658,041.63	14,488.72	105,993.41		

Total to first of previous month.

*Portion of work completed under contract 12 before contract 14 was executed reduces this amount by about 7%.
**Portion of work completed under contracts 4 and 8 before contract 17 was executed reduces this amount by about 7%.

CANVASS OF BIDS FOR CONTRACT 18, OPENED JANUARY 4, 1929.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
CONTRACT 18
FURNISHING IRON CASTINGS FOR THE WARE RIVER INTAKE WORKS OF THE WACHUSETT-COLDBROOK TUNNEL IN THE TOWN OF BARRE.

ITEM	DESCRIPTION	UNIT	QUANTITY	(1) THE ALDRICH PUMP CO. Front St. Allentown, Pa.		* (2) BARBOUR STOCKWELL CO. 205 Broadway Cambridge, Mass.		(3) GIBBY FOUNDRY CO. 96 Condor St. East Boston, Mass.		(4) WEATHERLY FOUNDRY & MFG. CO. Weatherly, Pa.		(5) BUILDERS IRON FOUNDRY Providence, R.I.	
				PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT
1	Shaft lining plates	Ton	243	58.90	14,312.70	63.70	15,479.10	70.00	17,010.00	80.00	19,440.00	77.40	18,808.20
2	Nozzle castings for shaft valves	Ton	23.4	122.00	2,854.80	77.90	1,822.86	120.00	2,808.00	148.50	3,474.90	238.80	5,587.92
3	Base castings for shaft valves	Ton	11.9	98.00	1,166.20	117.30	1,395.87	150.00	1,785.00	114.40	1,361.36	134.40	1,599.36
					18,333.70		18,697.83		21,603.00		24,276.26		25,995.48

ITEM	DESCRIPTION	UNIT	QUANTITY	(6) KUTZTOWN FOUNDRY & MACHINE CO. 1421 Chestnut St. Philadelphia, Pa.		(7) HARRISON SQUARE FOUNDRY CO. 110 Gisson St. Dorchester, Mass.		(8) HOLYOKE MACHINE CO. 81 Thomas St. Worcester, Mass.		(9) U.S. CAST IRON PIPE & FOUNDRY CO 1421 Chestnut St. Philadelphia, Pa.			
				PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT		
1	Shaft lining plates	Ton	243	82.00	19,926.00	110.00	26,730.00	120.00	29,160.00	INFORMAL LUMP SUM BID			
2	Nozzle castings for shaft valves	Ton	23.4	187.00	4,375.80	120.00	2,808.00	200.00	4,680.00				
3	Base castings for shaft valves	Ton	11.9	175.00	2,082.50	100.00	1,190.00	240.00	2,856.00				
					26,384.30		30,728.00		36,696.00		45,485.00		

* *Contract awarded to Barbour Stockwell Co. Jan. 8, 1929.*

Canvass of Bids for Contract No.19, opened July 16, 1929.

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission
Contract No.19. for Constructing the Dam and Substructure of the Intake Building for the Ware River Intake Works at Shaft 8 of the Wachusett-Colebrook Tunnel in the Town of Barre.

				* (1) J.W. Bishop Co. 109 Foster St. Worcester, Mass.		(2) The Tuller Construction Co. 95 Monmouth St. Red Bank, N.J.		(3) Monroe & Westcott Inc. Community Theater Bldg. No Attleboro, Mass.		(4) The Milton Construction & Engr'g. Corp. 141 Milk St. Boston, Mass.		(5) Winston & Co. Inc. 277 Fair St. Kingston, N.Y.		(6) Cenedella & Co. 68 School St. Milford, Mass.		(7) James J. Coughlan & Sons Inc. 27 School St. Boston, Mass.	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1.	Clearing.	Acre	5	95.00	$ 475.00	200.00	$ 1,000.00	200.00	$ 1,000.00	200.00	$ 1,000.00	90.00	$ 450.00	150.00	$ 750.00	150.00	$ 750.00
2.	Grubbing.	Acre	3	220.00	660.00	400.00	1,200.00	300.00	900.00	300.00	900.00	250.00	750.00	300.00	900.00	150.00	450.00
3.	Earth Excav. (below El. 642.)	Cu Yd.	5,000	1.85	9,250.00	2.00	10,000.00	3.00	15,000.00	5.00	25,000.00	3.00	15,000.00	6.00	30,000.00	7.50	37,500.00
4.	Earth Excav. (above El. 642.)	Cu Yd	4,000	1.20	4,800.00	1.25	5,000.00	2.00	8,000.00	3.00	12,000.00	1.50	6,000.00	1.50	6,000.00	6.50	26,000.00
5	Rock Excav.	Cu. Yd.	700	6.00	4,200.00	12.00	8,400.00	10.00	7,000.00	6.00	4,200.00	5.00	3,500.00	8.00	5,600.00	12.00	8,400.00
6.	River Control.	Lump Sum.			11,300.00		9,000.00		13,000.00		3,300.00		15,000.00		12,000.00		5,000.00
7.	B. & A.R.R. Culvert (in addition to other items)	Lump Sum			3,412.00		1,000.00		1,500.00		1,000.00		2,000.00		1,500.00		1,000.00
8	Refill & Embanking (Imperv. Mat'l)	Cu Yd	500	1.50	750.00	1.50	750.00	1.00	500.00	1.00	500.00	1.50	750.00	1.75	875.00	1.50	750.00
9.	Refill & Embanking (Perv. Mat'l)	Cu. Yd.	9,000	.90	8,100.00	.75	6,750.00	.60	5,400.00	.50	4,500.00	.90	8,100.00	1.00	9,000.00	1.50	13,500.00
10	Surface Dressing of Top Soil.	Cu. Yd	100	3.00	300.00	2.00	200.00	2.00	200.00	1.00	100.00	1.50	150.00	2.50	250.00	3.00	300.00
11.	Seeding & Grassing (if required)	Lump Sum.			170.00		60.00		100.00		100.00		100.00		800.00		1,000.00
12	Riprap.	Cu Yd.	4,000	2.00	8,000.00	1.00	4,000.00	2.00	8,000.00	5.25	21,000.00	3.00	12,000.00	2.00	8,000.00	3.00	12,000.00
13.	Paving.	Cu. Yd.	250	4.00	1,000.00	3.00	750.00	4.00	1,000.00	5.00	1,250.00	5.00	1,250.00	5.00	1,250.00	10.00	2,500.00
14	Crushed Stone, Gravel & Sand	Cu Yd	100	3.50	350.00	5.00	500.00	4.00	400.00	3.50	350.00	4.00	400.00	2.50	250.00	5.00	500.00
15.	Portland Cement.	Barrel	11,000	2.75	30,250.00	3.50	38,500.00	3.50	38,500.00	2.65	29,150.00	2.50	27,500.00	2.75	30,250.00	2.70	29,700.00
16.	Concrete Masonry, Class "A".	Cu. Yd	3,300	12.00	39,600.00	20.00	66,000.00	15.00	49,500.00	12.69	41,877.00	22.00	72,600.00	19.00	62,700.00	17.00	56,100.00
17.	Concrete Masonry, Class "B."	Cu Yd	2,900	12.00	34,800.00	11.00	31,900.00	12.00	34,800.00	11.00	31,900.00	16.00	46,400.00	11.00	31,900.00	16.00	46,400.00
18.	Dimension Stone Masonry	Cu Yd.	100	165.00	16,500.00	126.00	12,600.00	140.00	14,000.00	165.00	16,500.00	100.00	10,000.00	160.00	16,000.00	170.00	17,000.00
19	Ashlar Masonry	Cu.Yd	550	65.00	35,750.00	65.00	35,750.00	60.00	33,000.00	70.00	38,500.00	60.00	33,000.00	67.00	36,850.00	84.00	46,200.00
20.	Brick Masonry (for C.B., MH & Cesspool)	Cu Yd.	30	31.00	930.00	40.00	1,200.00	40.00	1,200.00	35.00	1,050.00	40.00	1,200.00	40.00	1,200.00	30.00	900.00
21.	Hollow Terra Cotta in bldg partitions.	Cu Yd.	5	31.00	155.00	35.00	175.00	50.00	250.00	20.00	100.00	30.00	150.00	22.00	110.00	30.00	150.00
22.	Granolithic Finish	Sq Yd	600	.75	450.00	1.50	900.00	1.50	900.00	.63	378.00	1.00	600.00	2.00	1,200.00	1.50	900.00
23	Grout.	Cu.Yd	200	8.00	1,600.00	5.00	1,000.00	8.00	1,600.00	7.00	1,400.00	10.00	2,000.00	16.00	3,200.00	10.00	2,000.00
24	Drilling holes in rock & masonry	Lin Ft	400	1.15	460.00	2.25	900.00	1.00	400.00	1.00	400.00	1.50	600.00	.75	300.00	.50	200.00
25.	Steel for reinforcing concrete	Pound.	260,000	.04½	11,700.00	.05	13,000.00	.05	13,000.00	.05	13,000.00	.06	15,600.00	.05½	14,300.00	.06	15,600.00
26.	Timber and Lumber.	M feet B.M.	50	107.00	5,350.00	120.00	6,000.00	100.00	5,000.00	100.00	5,000.00	100.00	5,000.00	120.00	6,000.00	125.00	6,250.00
27	Doors.	Lump Sum.			490.00		300.00		300.00		270.00		400.00		600.00		1,000.00
28.	C.I. Pipe & Spec. Castings, (flanged)	Pound.	50,000	.12	6,000.00	.08	4,000.00	.10	5,000.00	.14	7,000.00	.08	4,000.00	.10	5,000.00	.11	5,500.00
29	C.I. Pipe & Spec Castings, (b. & s)	Pound	7,500	.06	450.00	.07	525.00	.10	750.00	.14	1,050.00	.04	300.00	.07	525.00	.138	1,035.00
30	Galv. steel pipe & fittings, 6 inch.	Lin. Ft	100	9.00	900.00	2.00	200.00	9.00	900.00	2.00	200.00	4.00	400.00	2.00	200.00	12.32	1,232.00
31.	Galv. steel pipe & fittings, 10 inch.	Lin. Ft.	200	12.00	2,400.00	3.00	600.00	10.00	2,000.00	4.00	800.00	6.00	1,200.00	3.00	600.00	18.70	3,740.00
32.	Brass pipe and fittings	Pound.	4,000	.52	2,080.00	.50	2,000.00	.50	2,000.00	.50	2,000.00	.60	2,400.00	.60	2,400.00	.94	3,760.00
33	Vitrified sewer pipe, 8" to 12" inc.	Lin. Ft.	250	1.20	300.00	.80	200.00	1.00	250.00	1.50	375.00	1.00	250.00	1.50	375.00	1.00	250.00
34	Coring for & setting valve bases, etc	Pound	150,000	0.6½	1,875.00	.01	1,500.00	.02½	3,750.00	.03	4,500.00	.03	4,500.00	.05	7,500.00	.03	4,500.00
35.	Installing Oil Pressure System	Lump Sum.			700.00		400.00		200.00		1,000.00		1,500.00		900.00		450.00
36.	Coring for & Inst Vacuum Prim App	Lump Sum			600.00		500.00		200.00		550.00		500.00		800.00		600.00
37.	Coring for & inst. other Metal Work.	Pound	15,000	.02	300.00	.01	150.00	.03	450.00	.04	600.00	.04	600.00	.04	600.00	.03	450.00
38.	Electric Wiring	Lump Sum			1,000.00		1,000.00		600.00		1,200.00		500.00		600.00		1,850.00
39	Plumbing	Lump Sum			1,700.00		2,500.00		800.00		1,300.00		600.00		1,100.00		1,500.00
40.	Heating	Lump Sum.			4,520.00		3,500.00		4,500.00		4,500.00		2,800.00		4,700.00		5,000.00
41.	Automatic Shutters.	Lump Sum.			500.00		500.00		500.00		480.00		100.00		700.00		610.00
42.	Trash Racks	Pound	35,000	.09	3,150.00	.07	2,450.00	.08	2,800.00	.12	4,200.00	.12	4,200.00	.15	5,250.00	.13	4,550.00
43	Misc. C.I., W.I., & Steel.	Pound	75,000	.14	10,500.00	.10	7,500.00	.13	9,750.00	.12	9,000.00	.15	11,250.00	.12	9,000.00	.33½	24,375.00
44.	Galvanizing	Pound.	30,000	.05	1,500.00	.01	300.00	.05	1,500.00	.06	1,800.00	.04	1,200.00	.07	2,100.00	.06	1,800.00
45	Misc brass, bronze & copper.	Pound	600	1.00	600.00	.50	300.00	1.00	600.00	.50	300.00	.70	420.00	.75	450.00	1.10	660.00
46.	Demol & Rem White Valley Dam, etc	Lump Sum.			1,500.00		500.00		1,000.00		1,000.00		1,000.00		600.00		1,000.00
47.	Cleaning up.	Lump Sum.			1,700.00		1,000.00		1,000.00		1,000.00		1,000.00		1,000.00		1,500.00
	Totals				$ 273,077.00		$ 286,460.00		$ 293,000.00		$ 297,580.00		$ 319,220.00		$ 326,185.00		$ 396,412.00

* Contract awarded to J.W. Bishop Co. July 23, 1929.

Canvass of Bids for Contract 22 Opened Nov. 5, 1929.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

CONTRACT 22

Furnishing and Installing an Unwatering Pump in Shaft 1 of the Wachusett-Coldbrook Tunnel in the Town of West Boylston.

NAME	PUMP	MOTOR	COST	REMARKS
*F.A. Mazzur Co., Inc. 141 Milk St. Boston, Mass.	Warren Steam Pump Co.	General Electric	$11,975.00	Alternate: $500 to be deducted for Westinghouse instead of General Electric motor but without water tightness specified for motor casing.
Allis-Chalmers Mfg. Co. Milwaukee, Wis.	Allis-Chalmers	Allis-Chalmers	$14,300.00	
Turbine Equipment Co. of New England 80 Federal St. Boston, Mass.	De Laval Steam Turbine Co.	General Electric	$14,795.00	Alternates: $1330 and $1795 respectively to be deducted for 2 couplings not of stainless steel as specified.

* Contract awarded to F.A. Mazzur Co., Inc. Nov. 12, 1929.

Canvass of Bids for Contract 23 Opened November 5, 1929.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
CONTRACT 23
FOR MAKING BORINGS IN THE TOWNS OF BELCHERTOWN, ENFIELD, WARE, GREENWICH AND HARDWICK.

ITEM	DESCRIPTION	UNIT	QUANTITY	✱ (1) Sprague & Henwood Inc. Scranton, Pa. PRICE	AMOUNT	(2) Gray-Milaeger Drilling Co 123 Wisconsin Ave., Milwaukee, Wis. PRICE	AMOUNT	(3) The Giles Drilling Corporation 19 W. 44th St., New York, N.Y. PRICE	AMOUNT
1.	Wash borings	Lin. Ft.	300	2.45	735.00	3.00	900.00	2.75	825.00
2.	Core borings to surface of sound bed rock	Lin. Ft.	2,500	3.25	8,125.00	3.00	7,500.00	3.65	9,125.00
3.	Core borings in sound bed rock	Lin. Ft.	600	3.25	1,950.00	5.00	3,000.00	3.65	2,190.00
4.	Casing ordered left in place	Lin. Ft.	200	0.70	140.00	1.00	200.00	0.75	150.00
					$10,950.00		$11,600.00		$12,290.00

ITEM	DESCRIPTION	UNIT	QUANTITY	(4) Riley Drilling Co. 280 Broadway New York, N.Y. PRICE	AMOUNT	(5) Pennsylvania Drilling Company 1812 West Carson St. Pittsburgh, Pa. PRICE	AMOUNT	(6) Kennedy-Riegger Drilling Co. Inc. 30 Church St. New York, N.Y. PRICE	AMOUNT
1.	Wash borings	Lin. Ft.	300	2.50	750.00	4.00	1,200.00	6.50	1,950.00
2.	Core borings to surface of sound bed rock	Lin. Ft.	2,500	3.75	9,375.00	4.15	10,375.00	6.50	16,250.00
3.	Core borings in sound bed rock	Lin. Ft.	600	4.00	2,400.00	4.90	2,940.00	6.50	3,900.00
4.	Casing ordered left in place	Lin. Ft.	200	1.00	200.00	0.80	160.00	1.14	228.00
					$12,725.00		$14,675.00		$22,328.00

✱ Contract awarded to Sprague & Henwood Inc. Nov. 5, 1929.

Report of the Metropolitan District Water Supply Commission

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court Assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1930, its

FIFTH ANNUAL REPORT

I. Organization and Administration

There was no change in the personnel of the Commission during the year. Davis B. Keniston continued as chairman, and Charles M. Davenport and Joseph H. Soliday as associate commissioners. R. Nelson Molt continued as secretary.

The clerical force of the Commission's office at Boston remained the same throughout the year, and three special agents, under the direction of the Commission, continued to care for property acquired by the Commission in the Swift River and Ware River areas. Real Estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 123 employees during the year.

II. Engineering Department

Frank E. Winsor continued as chief engineer, and Karl R. Kennison as designing engineer and Walton H. Sears as mechanical engineer.

The field divisions were in charge of three division engineers as follows: Wachusett-Coldbrook Tunnel division, William W. Peabody; Coldbrook-Swift Tunnel division, Richard R. Bradbury; Swift River Reservoir division, N. LeRoy Hammond.

X. H. Goodnough, Chief Engineer of the State Department of Public Health, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, continued as consulting engineers. Charles T. Main of Boston was employed from time to time as consulting engineer on mill and water power damages, and Dr. Charles P. Berkey of Columbia University continued as geologist. Other consultants were employed from time to time as needed.

III. Offices

The office of the Commission and of the Chief Engineer continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston. The three division offices for the Wachusett-Coldbrook Tunnel, the Coldbrook-Swift Tunnel and the Swift River Reservoir Divisions continued at Holden Center, Hardwick Center and Enfield, respectively. The laboratory for water analysis, established in 1928, was removed to Enfield during the year to premises owned by the Commonwealth. The additional facilities secured thereby were utilized in soil testing, as well as for carrying on water analysis.

IV. Real Estate

During the year 104 new applications to the Commission were added to the 1,436 previously received from owners of real estate located in or near the Swift River Valley, making a total to date of 1,540 applications seeking to sell to the Commission a total of 60,787 acres within this area. The Commission has concluded the purchase of or has under option a total of 43,077 acres. Settlements were made for land takings along the line of the Wachusett-Coldbrook Tunnel and additional land was acquired for sanitary protection in the Ware River watershed above the intake works at Coldbrook.

The Commission continued, through duly appointed agents, the direction of the town government of the town of Prescott, as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

V. Progress

(a) General. — The bill in Equity filed by the State of Connecticut in the United States Supreme Court against the Commonwealth of Massachusetts, objecting to and seeking to enjoin the diversions from the Ware River and Swift River, authorized by the Massachusetts Legislature is still pending. The Honorable Charles W. Bunn of St. Paul, Minn., on December 2, 1929, was appointed by the United States Supreme Court as Special Master to take evidence of witnesses, and to make a report of his findings of fact and of law to the Court. Hearings were held, starting February 18, and ending March 21, 1930, at Boston, Mass., and Hartford, Conn., and final arguments of counsel were made at St. Paul, Minn., on April 23, and 24, 1930. On May 19, 1930, the Special Master filed his report with the United States Supreme Court, recommending that the bill in equity filed by the State of Connecticut be dismissed. The Commonwealth of Massachusetts was represented by the Honorable Joseph E. Warner, Attorney General, and the Honorable Bentley W. Warren as Special Counsel, together with Gerald J. Callahan, Esquire, and R. Ammi Cutter, Esquire, as Associate Counsel.

(b) Southern Sudbury Emergency Supply. — The Commission has consummated the settlement of all the claims for taking of real estate and diversion damages in the Southern Sudbury Emergency Supply growing out of the prosecution of the work authorized under the provisions of Chapter 111 of the Acts of 1927.

(c) Ware River Supply.— Work was continued by the West Construction Co., Assignee, under two contracts, numbered 14 and 17, for the construction of the Wachusett-Coldbrook Tunnel, and approximately 5.2 miles of tunnel were excavated, completing the total excavation of 14.2 miles of tunnel. The concrete lining of the side walls, arch and invert, or floor, of the tunnel, was carried on, and 13.9 miles of side walls and arch, and 6.5 miles of invert work was completed. The substructure of the outlet works of the Wachusett-Coldbrook Tunnel into the upper end of the Wachusett Reservoir at Shaft 1, West Boylston was practically completed. Contract No. 19 for the construction of a low diversion dam across the Ware River at the White Valley Mill Pond in Barre, Mass., for diverting the waters permitted to be diverted of the Ware River at Shaft 8, and for the construction of the substructure of the Intake Works was nearly completed.

Contracts numbered 24 and 25 were awarded to Munroe & Westcott, Inc., North Attleboro, on July 23, 1930, for the construction respectively of the superstructure of the Intake Building for the Ware River Intake Works at Shaft 8 of the Wachusett-Coldbrook Tunnel in the town of Barre, and for the construction of the superstructure of the Outlet Works at Shaft 1 of the Wachusett-Coldbrook Tunnel in the town of West Boylston, and work was in progress under these contracts.

A contract numbered 26 was awarded to Anderson-Coffey Co., Inc., of Boston, Mass., on September 24, 1930, for furnishing and installing electrical equipment at the outlet works at Shaft 1 of the Wachusett-Coldbrook Tunnel in the town of West Boylston.

A contract numbered 27 was awarded to Raymond A. Bergesson, of Sagamore, Mass., on September 24, 1930, for filling earth areas along the banks of the Ware River in the Town of Barre, above the intake works at Shaft 8 of the Wachusett-Coldbrook Tunnel.

(d) Swift River Supply. — Real Estate and topographic surveys were continued during the year. When requested by relatives or others interested, bodies were removed from the reservoir area and interred in other cemeteries, selected by those interested.

VI. Recommendation

The construction of the Ware River works for diverting the flood waters of the Ware River for the Metropolitan supply will be so far completed that this source of supply can be used during the year 1931.

The Commission has purchased some properties as a protection to the supply, and in conjunction with the Department of Public Health has made

studies of possible sources of pollution and the best methods of elimination.

There are several public and other hospitals and institutions within the watershed, the sanitary sewage from which constitutes a serious source of pollution.

The best method of elimination of this source of pollution appears to be by the construction of a sewer connecting these institutions and discharging into the Worcester sewerage system.

It is hoped that favorable arrangements can be made with these institutions, as well as with some of the towns within the area, by which a fair contribution to the cost of construction of this sewer may be obtained, and with the city of Worcester for receiving and disposing of the sewage.

It is doubtful if the provisions of Chapter 375 of the Acts of 1926 are broad enough to authorize the construction of this sewer, and it is recommended that a special act be passed substantially in the form of the bill submitted herewith. The cost should be paid from funds already provided for extending and increasing the water supply of the Metropolitan water system.

VII. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

VIII. Other Reports

The report of the Chief Engineer is herewith presented.

Respectfully submitted,
Davis B. Keniston, *Chairman*
Charles M. Davenport, *Associate Commissioner*
Joseph H. Soliday, *Associate Commissioner*
Metropolitan District Water Supply Commission.

20 Somerset Street, Boston, Massachusetts.
January 13, 1931

Report of the Chief Engineer

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1930.

ORGANIZATION

In numbers the engineering organization has not materially changed during the year.

Karl R. Kennison, Designing Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, the preparation of contract specifications, contract and working drawings.

Charles L. Coburn and Stanley M. Dore, Assistant Designing Engineers, continued their general supervision of the detailed work of the office.

Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. He has assisted in the design of work of a mechanical engineering nature and in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Swift River Reservoir Division.

Walter H. Junkins, Chemist, continued in charge of the Springfield Laboratory for water analyses which on May 1 was moved from Springfield to Enfield and placed under the general supervision of the Swift River Reservoir Division.

X. H. Goodnough, Chief Engineer of the State Department of Public Health until his retirement on October 23, and J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, continued as Consulting Engineers. Dr. Charles P. Berkey of Columbia University has advised on geological matters. Charles T. Main, consulting engineer of Boston, and other experts were employed from time to time as required.

The employees under the direction of the Chief Engineer at the end of the year and of the preceding year were as follows:

PERSONNEL OF ENGINEERING DEPARTMENT

CLASSIFICATION	Nov. 30, 1929	Nov. 30, 1930
HEADQUARTERS OFFICE, CHIEF ENGINEER AND DESIGNING DIVISION:		
Chief Engineer	1	1
Designing Engineer	1	1
Mechanical Engineer	1	1
Assistant Designing Engineers	2	2
Assistant Engineers	9	8
Draftsmen	7	7
Instrumentmen	1	–
Senior Stenographer	1	1
Stenographers	3	4
Clerks	2	2
File Clerks	2	1
Office Boy	1	1
	31	29
HOLDEN OFFICE, WACHUSETT–COLDBROOK TUNNEL DIVISION:		
Division Engineer	1	1
Assistant Engineers	8	8
Draftsmen	2	2
Instrumentmen	3	5
Rodmen	3	3
Axemen	7	2
Inspectors	9	30
Stenographer	1	1
	34	52

Classification	Nov. 30, 1929	Nov. 30, 1930
Hardwick Office, Coldbrook–Swift Tunnel Division:		
Division Engineer	1	1
Assistant Engineers	4	5
Draftsmen	2	2
Instrumentmen	4	4
Rodmen	4	4
Axemen	4	1
Inspectors	3	3
Gage Tender	1	1
Stenographer	1	1
	24	22
Enfield Office, Swift River Reservoir Division:		
Division Engineer	1	1
Assistant Engineers	6	7
Draftsmen	1	2
Instrumentmen	6	5
Inspector	–	1
Rodmen	7	2
Axemen	4	2
Clerk	–	1
Stenographer	1	–
Caretaker	1	1
Chemist	–	1
Laboratory Assistant	–	1
	27	24
Springfield Laboratory *		
Chemist	1	–
Assistant Engineer	1	–
Assistant Chemist	1	–
Instrumentman	1	–
Boatman	1	–
Clerk	1	–
	6	–
Total Engineering Force	122	127

* Transferred to Swift River Reservoir Division on May 1.

The maximum force during the year was 130. during the weeks ending July 12 to August 16, inclusive. The minimum force was 118, during the weeks ending January 18 to February 15, inclusive, and during the week ending May 3. The average force for the year was 123.

Offices

The office of the Chief Engineer and Designing Division was continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Swift River Reservoir Division was continued in the property of the Commission formerly known as the Frances W. Chandler house on Quabbin Road. The laboratory for water analysis was continued in the Markarian Building, 175 State Street, Springfield, until the first week in May, during which the personnel and equipment were moved to Enfield and re-established in property of the Commonwealth formerly known as the Barlow House in Enfield where also a laboratory for soil testing was established in the Swift River Reservoir Division.

Headquarters Office

Summary of Year's Work

Connecticut Case. — In connection with the bill in equity filed by the State of Connecticut in the United States Supreme Court against the Commonwealth of Massachusetts, seeking to enjoin the diversions from the Ware and Swift rivers, data was prepared for the use of the attorneys and experts in the preparation and presentation of testimony and arguments before Charles W. Bunn, Special Master, who was appointed by the Court on December 2, 1929. Hearings before the Special Master were held from February 18 to March 21 in Boston and Hartford and arguments of counsel were presented in St. Paul, Minn., April 23 and 24, 1930. The Special Master filed his report with the Court on May 19. The case is still pending.

Real Estate. — In the Swift River Reservoir area, 1,798 acres were offered for sale by their owners this year, making a total so offered to date of 60,787 acres. Reports and recommendations were submitted to the Commission with respect to purchasing the same.

PROGRESS OF REAL ESTATE NEGOTIATIONS FOR SWIFT RIVER RESERVOIR
OWNERS' OFFERS TO SELL TO COMMONWEALTH

	Number of Offers	Total Area (Acres)	Area Not Required (Acres)	Title Vested In Commonwealth (Acres)
Total for Year ending Nov. 30, 1930	104	1,798	1,048	5,876
Total to Nov. 30, 1929 . . .	1,436	58,989	7,081	34,786
Total to Nov. 30, 1930 . . .	1,540	60,787	8,129	40,662

Options Outstanding Nov. 30, 1930 include 2,415 Acres.
Acreage is mainly based upon estimates obtained from deeds or other information and not from surveys.

Preliminary studies were continued of highway and railroad relocations.

One taking plan covering 18 parcels of land in the town of Hopkinton was prepared and filed during the year. These parcels were swamp lands bordering the open channel constructed by the Commission to divert the waters of Whitehall Pond into Hopkinton Reservoir.

Contracts and Specifications. — Working drawings for contracts 14, 17 and 19 were prepared and issued and monthly estimates were prepared for contract 18. Plans and specifications were prepared for extending the Wachusett-Coldbrook tunnel to the Swift River by constructing the Coldbrook-Swift tunnel in the towns of Barre, Hardwick and Greenwich.

Plans and specifications were prepared for contract 24, for constructing the superstructure of the intake building for the Ware River intake works at Shaft 8 of the Wachusett-Coldbrook tunnel in the town of Barre; and for contract 25, for constructing the superstructure of the outlet works at Shaft 1 of the Wachusett-Coldbrook tunnel in the town of West Boylston. Both contracts were executed on July 23rd. Subsequently, working drawings, which included the preparation of shop details of the structural steel, were prepared, covering the work of construction.

Plans and specifications were prepared for contract 26, for furnishing and installing power and lighting wiring and electrical equipment at the outlet works at Shaft 1 of the Wachusett-Coldbrook tunnel, in the town of West Boylston. The contract was executed September 24th.

Plans and specifications were prepared for contract 27, for filling with earth areas along the bank of the Ware River in the town of Barre. The contract was executed September 23rd.

Inspection and Tests. — E. L. Conwell and Company of Philadelphia, Pa., continued the testing of cement. The Worcester Polytechnic Laboratory continued the testing of concrete cylinders. William R. Conard of Burlington, New Jersey, continued with mill inspection of control valves and equipment for the Ware River intake works at Shaft 8. The inspection of the castings made under contract 18 was continued by the engineering force who also inspected the steel tunnel bulkhead required for the tunnel west of Shaft 8, miscellaneous equipment furnished for the Ware River intake works under Contract 19 and structural steel work furnished under Contracts 24 and 25.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey and further discharge measurements were made from time to time to define the rating curve more exactly.

The gaging station on the Chicopee River at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and also with the United States Geological Survey and further discharge measurements were made to define the rating curves of the water wheels and the dam more exactly.

The gaging station on the Swift River at the plant of the Boston Duck Mills of the Otis Company at Bondsville was continued.

The gaging station on the Connecticut River at Thompsonville, Connecticut, located at the "Enfield Dam," so called, was continued in cooperation with the

United States Geological Survey and further measurements were made to define the rating curves of the dam and canal more exactly.

In connection with the examination of the waters of the Ware, Swift, and Chicopee rivers, observations of flow were continued from time to time and additional temporary gaging stations established as required.

Tercentenary Exhibition. — The Commission participated in an exhibition of the activities of the various departments of the Commonwealth which was shown at the Eastern States Exposition in West Springfield, Massachusetts, from September 14 to 20, inclusive, and at the Commonwealth Armory in Boston from September 29 to October 12, inclusive. Exhibits prepared for this purpose included a large wall map of the Metropolitan District and its water supply sources, bordered by photographs of the principal features of the existing works, the sites of the proposed construction on the Ware and Swift rivers, and views of the work under construction. These photographs included a number of aerial photographs made for the purpose of this exhibit, and showed prominent features of the existing water supply, and of the work under construction and also the sites of proposed work. The exhibits also included a large perspective water color drawing of the Ware River intake works. The Commission also took and exhibited motion pictures of its construction work and of other activities of the Metropolitan District Commission. Members of the engineering force were present to show the pictures and explain the exhibits.

Design of Structures

Shaft 1. Outlet Works. — The superstructure of the outlet works was designed to present an attractive appearance and to require a minimum of maintenance. The exterior walls are of granite with a slightly reddish tinge from quarries in Townsend, Massachusetts. The inside wall surface to a height of about five feet and around the window and door openings is of tile of variable brown tones. Above the five foot level a slightly mottled face brick of lighter tone is used. Door and window frames are of bronze. The roof is of slate on precast gypsum slabs. The building has a structural steel frame work which provides the necessary wind bracing in walls and roof and supports the roof and the bridge crane girders. Steel roof members will be encased in a protective coating of cement mortar. The building is intended to house a possible future hydro-electric generating unit and gates to control the discharge from the tunnel into the reservoir. At present, no equipment will be installed in the building except the traveling bridge crane, the venturi meter and the pumping equipment required to unwater the tunnel. The traveling bridge crane which was purchased but not installed has two hoists. The main hoist with a capacity of 20 tons, and a lift of 35 feet, will be hand operated and is intended for the handling of future tunnel control gates and hydro-electric equipment. An auxiliary hoist with a capacity of 5 tons and a lift of 240 feet, will be electrically operated and will serve to handle stop shutters in the outlet channel, loads into and out of the tunnel through the main waterway shaft and the 900 h.p. motor and its 20 mil. gal. daily capacity centrifugal pump at the bottom of the unwatering pump shaft. The facing of the concrete abutments of the existing dam across the Quinapoxet River near the tunnel outlet channel at Shaft 1 with stone masonry was included in Contract 25, for constructing the superstructure of the outlet works.

Shaft 8. Ware River Intake Works. — The superstructure of the Ware River intake works is similar in design to that of the outlet works at Shaft 1. The oil burning steam heating plant which was installed in the basement under Contract 19 was designed to be extended to take care of heating the superstructure. An air-lift water supply was designed to take a supply from a seam in sound bed rock which was encountered at a depth of about 90 feet when Shaft 8 was first excavated. The air compressor required in the operation of the main control valves at the top of Shaft 8 has been adapted for use with this air lift and the necessary piping, including an air lift foot piece at a depth of about 170 feet was embedded in the concrete behind the cast iron lining at Shaft 8. This air lift has been in satisfactory operation by the Contractor during the greater part of the year.

Studies were made of the requirements for crane service and a traveling bridge crane was purchased having a single electrically operated hoist with a capacity of 7½ tons and a lift of 80 feet. It is intended for the handling of heavy equipment such as the valve and meter castings in the main valve pit. By a change in the reeving which can be made at any time, this hoist will have a capacity of one-half ton and a lift of 302 feet and will serve to handle loads into and out of the tunnel through an opening provided in the bottom of the main valve pit. It will also serve to handle screens, racks and stop shutters that are provided across the inlets to the various siphon spillways and sluice gates and, through openings in the main floor, stop shutters that are provided in the crests of all the siphon spillways.

Shaft 4. Superstructure. — Studies were made of the requirements at the top of Shaft 4 for a building to house hoisting equipment to provide access to the tunnel and to allow for handling a boat into and out of the tunnel. Future inspection of the tunnel may be made by boat between Shafts 12 and 4 and possibly easterly to Shaft 3. Inspection of the tunnel east of Shaft 3 cannot be made by a boat.

Main Dam and Dike. — Studies were continued of the location of the main dam and dike for the proposed Swift River Reservoir and of the requirements for a diversion tunnel in sound bed rock through the hill which forms the west abutment of the dam, to control the flow of the river during the construction of the main dam.

Water Supply Yield. — Studies were made of the safe yield of the combined sources of water supply both existing and proposed, including the preliminary diversion of the Middle and East Branch of the Swift river.

Power for Dam and Tunnel Extension. — Studies were continued of the power requirements for construction of the main dam and dike of the Swift River Reservoir and of the proposed Coldbrook-Swift Tunnel.

Tunnel Extension to Swift River Reservoir. — Progress was made on plans and specifications for the extension of the tunnel westerly from Coldbrook to the proposed Swift River Reservoir. The location of four shafts was determined, numbered 9 to 12 inclusive. Shaft 12 is located near the flow line of the Swift River Reservoir and will serve as the intake from the reservoir, provision being made for drawing water from various elevations and for operating stop shutters and screens from a building located over this shaft. Access by boat to the completed Swift-Wachusett Tunnel is provided at three points, namely shafts 4, 9, and 12. A pier in the center of the tunnel, at shafts 4 and 9, will allow stop planks to be inserted from a working platform just above the tunnel roof, to facilitate not only the inspection of the tunnel by boat or otherwise, but also at shaft 9 to create a sump for a supplementary tunnel unwatering pump. A chamber will be excavated near the bottom of shaft 9, in which such a pump may be installed. Access to the tunnel may also be obtained through manholes in the superstructure at shafts 1 and 8.

Tunnel Markers. — Tiles for marking stations along the tunnel have been purchased and are being installed. These are hard burned "Ohio flint" paving tiles 6″ x 6″ with the station numbers in "Tuscan inlay." These are being fastened with bronze bolts to the south tunnel wall and are 4½ feet above the invert grade and at intervals of 500 feet along the tunnel.

Protection of Water Supply. — Studies for removal of sewage from parts of Rutland and Holden to safeguard the water supply of the Metropolitan District were made and a bill providing for a trunk sewer was prepared for submission to the legislature.

Springfield Laboratory

At the Laboratory in Springfield the analyses of water samples taken in the Connecticut River and its tributaries were continued until early in May, and studies were made of the quality of water in the Ware, Swift and Chicopee rivers. After the first week in May the personnel and equipment were re-established in the Swift River Reservoir Division at Enfield.

Wachusett-Coldbrook Tunnel Division — Holden Office

The Wachusett-Coldbrook Tunnel Division continued in charge of the construction of the Wachusett-Coldbrook Tunnel, with the exception of Shaft 8, and has charge of the construction of the tunnel outlet works at Shaft 1. The division office was continued at Holden Center and six field offices at Shafts 1, 2, 4, 5, 6 and 7. The field office at Shaft 6 was discontinued about August 2, when work at this shaft was sufficiently completed to permit dismantling the construction plant.

Office Work

Tunnel sections were plotted and excavation and masonry volumes computed therefrom. Semi-monthly estimates were prepared for Contracts 14 and 17, and monthly estimates for Contracts 10 and 25. Additional geological field notes and specimens were prepared for a permanent geological record. Studies were continued of the character of materials available for concrete aggregates from the tunnel excavations and these data applied as required as the various concreting plants for placing the tunnel lining were constructed.

Field Work

Lines and grades were given for construction work on Contracts 14, 17 and 25. Photographs of the construction work and of the rock formations of geological interest in the tunnel were continued.

Weekly observations of water color samples along the Ware River and its tributaries were continued. After June 17 these observations were made by the Coldbrook-Swift Tunnel Division office.

The State Department of Public Health continued its cooperation with this division in the analysis of samples of drinking water used in the different contractors' camps and of sewage effluents, and also continued its seasonal investigations of mosquito breeding with reference to the prevention of malaria.

Records were kept of the amount of cement used and required to be used at all points of the work including that portion of the tunnel under the supervision of the Coldbrook-Swift Tunnel Division, the total amount used during the year being well over 200,000 bbls. The inspectors employed to test the cement at the mills before shipment were kept advised in advance of all requirements.

Progress of Contracts

Contract 10. — Contract 10 with the New England Power Company, for constructing, maintaining and operating a 22,000-volt transmission line along the Wachusett-Coldbrook Tunnel line, was in force throughout the year. Cost of operation and maintenance for the twelve months ending October 1st was $9,069.92.

Electrical power was purchased from this company by the contractors on Contracts 14 and 17. The total power furnished during the year was 15,439,600 KWH including line and transformer losses. This total after line losses (but including transformer losses) was distributed to the different shafts as follows:

	KWH
Shaft 1	308,466
Shaft 2	3,597,176
Shaft 3	0
Shaft 4	2,917,526
Shaft 5	1,836,725
Shaft 6	983,790
Shaft 7	2,404,298
Shaft 8	3,293,448
Total	15,341,429

The power was furnished continuously throughout the year with only a few minor interruptions.

Wachusett-Coldbrook Tunnel. — Work on the tunnel was prosecuted throughout the year under Contracts 14 and 17 by the West Construction Co., who continued to lease from the Commission various buildings at West Rutland as general headquarters, and to employ local physicians who made weekly reports on the health of the contractors' employees and on the sanitary condition at

each of the contractors' camps. The progress of excavating and lining the entire length of the tunnel is shown graphically on a chart appended to this report.

Briefly stated, the excavation was completed and the concrete lining begun and nearly completed during the year. The following is a summary of the differences in line and grade at the points where the excavations met between shafts.

Shaft	Distance Apart	Difference Line	Difference Grade	Point of Meeting
1—2	9,902 ft.	.33 ft.	.01 ft.	836 ft. from Shaft 1
2—3	9,167 ft.	1.85 ft.	.02 ft.	8,537 ft. from Shaft 2
3—4	8,819 ft.	.81 ft.	.04 ft.	1,481 ft. from Shaft 3
4—5	11,633 ft.	.24 ft.	.02 ft.	5,814 ft. from Shaft 4
5—6	11,102 ft.	.49 ft.	.13 ft.	6,329 ft. from Shaft 5
6—7	9,232 ft.	.31 ft.	.07 ft.	4,732 ft. from Shaft 6
7—8	10,048 ft.	.09 ft.	.14 ft.	5,545 ft. from Shaft 7

For lining the tunnel with concrete, materials were crushed and proportioned on the surface, dropped down the shaft, and transported along the tunnel to the mixer, from which the concrete was forced by compressed air into the space between the irregular rock walls and the smooth steel forms. These forms were collapsible and moved ahead a section at a time, the entire operation being continuous. The invert or floor was poured separately, the operation resembling the building of a long concrete sidewalk. The method of lining is described in detail hereinafter.

Contract 14. — Contract 14 is for the construction of the east portion of the Wachusett-Coldbrook Tunnel through West Boylston, Holden and Rutland and extends from Shaft 1 at the upper end of the Wachusett Reservoir near Oakdale to a point which was established during the year at 5,814 feet west of Shaft 4 and 5,819 feet east of Shaft 5. At the end of the year about 96% of the value of the work had been completed. This included the completion of Shaft 1 and of that portion of the substructure of the outlet works that was required under this contract. It also included the completion of the tunnel excavation, a length of about 7,911 feet of tunnel being excavated during the year, making a total under this contract of 29,892 feet, and a total continuous length under this and previous contracts of 33,702 feet.

The tunnel was completely lined for a length of 1,036 feet. and in addition 31,215 feet of side walls and arch were placed. A length of 526 feet was lined in the previous year, and there remain to be lined under this contract 925 feet of side walls and arch and 32,140 feet of invert.

Three complete tunnel concrete plants were used for placing the sidewalls and arch and were moved from point to point as required along the entire length of the Wachusett-Coldbrook Tunnel, irrespective of contract limits.

The value of work included in contract estimates during the year was $1,398,896.17 or a total to November 15, the date of the last estimate, of $3,231,296.96 of which $3,033,167.26 or about 94% has been approved for payment.

Shaft 1. — No further tunnel excavation or lining was done from this shaft, the total distance excavated being 836 feet. At the beginning of the year, the steel linings of the waterway and pump shafts, and the concrete outside these linings with the pump discharge and ventilating pipes embedded therein had been placed up to about elevation 367.

At the end of the year all work was completed except a small amount of grading, placing of gratings and covers over openings at the top of shaft, removing office building and pumping equipment, and cleaning up.

Concreting inside the steel lining at the bottom of the pump shaft was begun on December 8 and continued until February 5 when this lining had reached elevation 367 near the top of the steel lining then in place, after which the galvanized iron ladder, landing platforms, and 6″ pipe casing for the deep well sump pump were installed for this portion of the shaft. A continuous staging was carried up the shaft with the lining.

On February 24, work was begun on placing concrete at the bottom of the waterway shaft connecting the shaft with the tunnel concrete previously placed, this work being completed on March 1. A continuous staging was then erected

CONTRACT 14. — Holing Through between Shafts 1 and 2.

CONTRACT 14. — Steel Forms for Lining Tunnel Sidewalls and Arch, Showing a Section of Forms Collapsed for Telescoping Through Section Set in Place.

in the waterway shaft to about elevation 306 near the bottom of the venturi meter.

Concreting of the transition section and interior lining of the steel in the waterway shaft was begun on March 22 and on April 7 had reached elevation 359 near the top of the steel lining then in place. This portion of the lining included the construction of the greater portion of the 90″ venturi meter and the setting of its two ring castings of bronze.

Placing of steel linings of the waterway and pump shafts was resumed on April 22 and was completed on May 16. The concrete outside these linings, including pump discharge and ventilating pipes and heavy reinforcement of the upper portion around the waterway shaft and ducts for electric wiring of the superstructure was completed to elevation 408.83 on July 11.

After the steel lining of the pump shaft was completed, the inside concrete lining was brought up in lifts of about eight feet, this lining being completed on June 4, including installation of ladder, landing platforms and 6″ casing for the deep well sump pump. The inside concrete and mortar lining of the waterway outlet shaft was completed on July 29.

The four 16″ pipe float wells were installed in the float chamber including all small piping, during July. For concrete aggregate, gravel was obtained from Millbury and sand from Worcester.

Grouting of the entire shaft and adjacent section of the tunnel was begun on August 5 and completed on August 11. All grouting was done from the waterway shaft, beginning at the bottom and connecting with grout pipes left in the lining, which connected at frequent intervals with the rock exterior of the concrete.

The grout was mixed in proportion of one part of cement to from 3 to 7 parts of water, no sand being used. A total of 98 cu. yds. of grout was used, and practically all leakage into the shaft was cut off.

Beginning on June 29, the 20″ discharge line was used by the contractor to pump water from the tunnel with a 2,000 gal. per min. centrifugal pump installed in the bottom of the pump shaft and connected with the 20″ valve on the intake from the tunnel. This pumping will be necessary until the completion of the tunnel.

The contractor's force averaged nine men. The average number of persons occupying the camp to May 23 was 5, the maximum population being 8 during the weeks ending May 2 and May 16. The buildings used for camp purposes were removed in August.

The only items of plant at this shaft at the end of the year were:

1 Air compressor 642 cu. ft. per min. capacity, run by 125 H. P. motor.
1 14′–0″ x 4′–6″ air receiver tank.
1 Centrifugal pump, rated at 2,000 gals. per min., under about 250 foot head, driven by 200 H. P. motor.

Shaft 2.—Tunnel excavation was completed on June 15 the lengths excavated being as follows:

Location	Under a Previous Contract	Under Contract 14 — To Nov. 30, 1929	Under Contract 14 — Year Ending Nov. 30, 1930	Total
East Heading	868 ft.	5,102 ft.	3,096 ft.	9,066 ft.
West Heading	903 ft.	6,272 ft.	2,277 ft.	9,452 ft.
Total	1,771 ft.	11,374 ft.	5,373 ft.	18,518 ft.

Drilling and mucking was continued in the same manner as described in the previous report.

As the west heading approached the tunnel excavated easterly from Shaft 3, a pilot drill hole was projected beyond the holes drilled for the regular shooting round, to drain the water which had accumulated to within 52 feet of the top of Shaft 3, approximately 1,470,000 gallons. On March 1, a hole 33 feet long connected with the old tunnel, and as soon as practicable, March 3, two additional drain holes were drilled. Excavation was resumed on March 6 and the tunnel was holed through as a top heading on March 10. The remaining bench was then excavated by lowering its height gradually in order to prevent overloading the Shaft 2 pumps, and the track and power, ventilation and pipe lines were extended to the west heading of the Shaft 3 tunnel. On March 30

excavation was begun at the west heading of Shaft 3 and continued until May 13, when because of soft rock, excavation was discontinued until a short stretch of 35 feet could be supported by permanent timbering. On May 21, excavation was resumed and continued until June 11 when the heading was "holed thru" to the east heading of Shaft 4. On June 15 the east heading was "holed thru" to the west heading of Shaft 1, being the last heading to be holed through on the Wachusett-Coldbrook Tunnel. The rock was of good quality except for the instance mentioned above, and for a short stretch in the east tunnel where, due to popping rock, considerable scaling of the arch was necessary.

Trimming and grading of the tunnel was begun as soon after holing through as the ventilation pipe and shooting lines could be removed. All rock on the sides and roof which projected beyond the "A" line was removed and the invert was brought to sub-grade by the removal of all tunnel muck above the "B" line and the filling in of all low areas up to the "B" line.

The average weekly progress on tunnel excavation was 110.0 feet easterly and 92.1 feet westerly. The maximum combined progress was in the week ending May 10 when 116.0 feet were excavated in the east section and 116.0 feet in the west section.

The contractor's force averaged 111 men per day up to September 13, and after this date, during the tunnel lining operation, 193, the average throughout the year being 128, three shifts being employed.

The average number of persons occupying the camp throughout the year was 48, the maximum population being 70 during the week ending March 7.

There has been no material change in plant items during the year, except for the installation of tunnel lining plant described elsewhere in this report. One additional air compressor with a capacity of 751 cu. ft. per min., driven by 150 H. P. motor, was transferred from Shaft 6, making the combined compressor capacity 2,677 cu. ft. per min. Eight more pumps were used, making 23 in all, on the tunnel construction, the largest having a rated capacity of 1,000 gals. per min. under a 100-ft. head, driven by a 40 H. P. motor.

Shaft 3. — The only work done at this shaft was the construction of the concrete shaft collar, and the pre-cast beams and slabs which will be placed over the top. These have not yet been placed in position. A total length of 1,196 feet of tunnel had been excavated from this shaft (under a previous contract), 630 feet easterly and 566 feet westerly.

Shaft 4. — Tunnel excavation was completed on April 4, the lengths excavated being as follows:

Location	Under a Previous Contract	Under Contract 14 — To Nov. 30, 1929	Under Contract 14 — Year Ending Nov. 30, 1930	Total
East Heading . .	442 ft.	5,139 ft.	1,757 ft.	7,338 ft.
West Heading . .	401 ft.	4,632 ft.	781 ft.	5,814 ft.
Total . . .	843 ft.	9,771 ft.	2,538 ft.	13,152 ft.

Drilling and mucking was continued in the same manner as described in the previous report.

On January 4 wet ground was encountered approximately 6,033 feet east of the shaft which resulted in temporarily slowing down the progress in this heading. On January 20 the west heading was holed through to the east heading from Shaft 5, and a wooden bulkhead was constructed to cut off air circulation between the shafts. The ventilation pipe and shooting lines were then removed, the sides and roof trimmed as required and the invert graded.

The use of "gunite" to stabilize the roof, as described in a previous report, was continued in the west tunnel to the point of holing through and for about 1,200 feet into the tunnel excavated from Shaft 5 except for a short stretch of 177 feet which did not require treatment, the total length of roof so treated being about 4,437 feet.

On April 4 tunnel excavation was suspended in the east heading, the remaining tunnel between Shafts 3 and 4 being excavated from Shaft 2. Trimming and grading of the tunnel in both the east and west tunnels was completed June 7. During the week ending June 14 the short stretch of temporary timbering in

the east tunnel was removed. The average weekly progress on tunnel excavation was 98.4 feet easterly and 107.1 feet westerly. The maximum combined progress was in the week ending December 7 when 101.0 feet were excavated in the east section and 92.5 feet in the west section. The maximum weekly progress in the east tunnel after suspension of tunnel driving in the west was 154.0 feet, during the week ending March 29.

The contractor's force averaged 81 men per day up to June 21, and after this date, during the tunnel lining operations, 128, the average throughout the year being 101, three shifts being employed. The average number of persons occupying the camp throughout the year was 37, the maximum population being 75 during the week ending August 22.

There has been no material change in plant items during the year, except for the installation of tunnel lining plant described elsewhere in this report. Four more pumps were used, making 15 in all on the tunnel construction, the largest having a rated capacity of 700 gallons per minute under a 100-foot head, driven by a 30 H. P. motor. The combined compressor capacity continued at 1,926 cu. ft.

The total work done and materials furnished to date under the principal items of Contract 14 are as follows:

Earth excavation for shafts	1,108	cu. yds.
Rock Excavation in shafts and in tunnel within 50 ft. of shafts	3,175	cu. yds.
Excavation in tunnel, except within 50 ft. of shafts	205,427	cu. yds.
Shaft & tunnel drainage	23,086	lin. ft.
Forms for preliminary concrete lining, Shaft 1	218	lin. ft.
Forms for concrete lining in tunnel	32,774	lin. ft.
Concrete masonry in shafts	2,468	cu. yds.
Concrete masonry in tunnel	65,246	cu. yds.
Concrete masonry not in shafts and tunnel	2,406	cu. yds.
Temporary timbering in tunnel	4.25	M ft. B. M.
Portland cement	105,413	bbls.
Earth excavation except for shafts	19,239	cu. yds.
Rock excavation except in shafts or tunnel	1,602	cu. yds.
Refilling and embankment	19,406	cu. yds.
Miscellaneous cast iron, wrought iron and steel	399,620	lbs.

Contract 17. — Contract 17 is for the construction of the west portion of the Wachusett-Coldbrook Tunnel through Rutland, Oakham and Barre, and extends westerly from the work covered by Contract 14, the work being prosecuted from Shafts 5, 6, 7 and 8. Excavation was continued by the same method as described in the previous reports.

At the end of the year approximately 98 per cent of the value of the work had been completed. This included the completion of Shaft 8 and of the tunnel excavation, a length of about 2,213 feet of tunnel being excavated during the year, making a total under this contract of 36,770 feet and a total continuous length under this and previous contracts of 41,199 feet.

The lining under this contract extends to within 31 feet of the west end of the excavation. The tunnel was completely lined for a length of 33,484 feet and in addition 7,628 feet of side walls and arch were placed. There remain to be lined under this contract 56 feet of side walls and arch (mainly at the bottom of Shafts 5 and 7) and 7,684 feet of invert.

The value of work included in contract estimates during the year was $1,407,130.23 or a total to November 15, the date of the latest estimate, of $4,065,171.86, of which $3,933,654.67 or about 97 per cent has been approved for payment.

Shaft 5. — Tunnel excavation was completed on January 1, the lengths excavated being as follows:

Location	Under a Previous Contract	Under Contract 17 — To Nov. 30, 1929	Under Contract 17 — Year Ending Nov. 30, 1930	Total
East Heading	670 ft.	5,149 ft.	– ft.	5,819 ft.
West Heading	697 ft.	5,270 ft.	363 ft.	6,330 ft.
Total	1,367 ft.	10,419 ft.	363 ft.	12,149 ft.

At the beginning of the year, tunnel excavation had been completed in the east heading and trimming and grading, in preparing for lining, was in progress.

The average weekly progress on tunnel excavation westerly was 77.8 feet,

the maximum progress being in the week ending December 14 when 86.8 feet were excavated.

The contractor's force averaged 69 men per day during the period of tunnel excavation when two shifts were employed and 78 during the period of tunnel lining when three shifts were employed, the average throughout the year being 78. The average number of persons occupying the camp throughout the year was 35, the maximum population being 58 during the week ending May 30.

There has been no material change in plant items during the year, except for the installation of tunnel lining plant described elsewhere in this report. One more pump was used, making 6 in all on the tunnel construction, the largest having a rated capacity of 300 gallons per minute under a 670-foot head, driven by a 100 H. P. motor. The combined compressor capacity continued at 2,341 cubic feet per minute.

Shaft 6. — At the beginning of the year tunnel excavation had been completed and trimming and grading, in preparation for lining, was in progress. A total length of 9,504 feet of tunnel was excavated from this shaft, 4,772 feet easterly including 671 feet under a previous contract, and 4,732 feet westerly including 669 feet under a previous contract. On January 5 the first forms for lining the arch and sidewalls were erected in the tunnel 856 feet west of this shaft.

During the week ending June 28, work was begun on concreting the shaft and tunnel connection, and pre-casting the slabs and beams for the shaft covering. The shaft timbering was removed except the head-frame. During the latter part of July the shaft site was vacated, and all camp buildings except the contractor's office, compressor and hoist houses were removed. During November the invert in the tunnel immediately adjacent to the shaft was completed with concrete mixed at the top of the shaft and lowered in buckets.

The contractor's force averaged 10 men. The average number of persons occupying the camp to February 7 was 6, the maximum population being 25 during the week ending January 3.

There has been no material change in plant items during the year. Seven pumps were continued in use, the largest having a rated capacity of 300 gallons per minute under a 670-foot head driven by a 100 H. P. motor. The combined compressor capacity continued at 1,511 cubic feet per minute.

Shaft 7. — Tunnel excavation was completed on February 6, the length excavated being as follows:

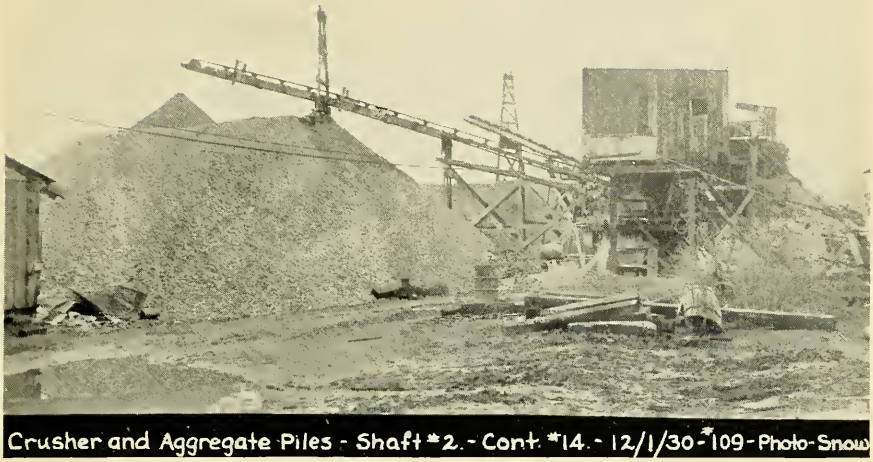
		Under Contract 17		
Location	Under a Previous Contract	To Nov. 30, 1929	Year Ending Nov. 30, 1930	Total
East Heading . .	861 ft.	3,639 ft.	– ft.	4,500 ft.
West Heading . .	861 ft.	4,137 ft.	547 ft.	5,545 ft.
Total . . .	1,722 ft.	7,776 ft.	547 ft.	10,045 ft.

At the beginning of the year tunnel excavation had been completed in the east heading and trimming and grading, in preparation for lining, was in progress in the east section.

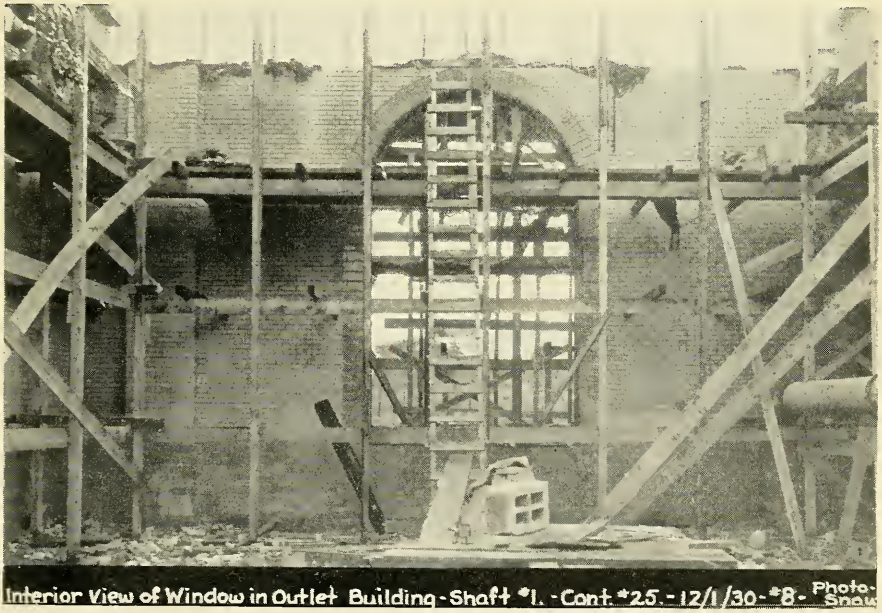
On February 6 the west heading was holed through from the east heading of Shaft 8 and a length of 105 feet of unexcavated bench, the excavation of which had been delayed by an increased leakage of water into the tunnel approximately 5,440 feet west of Shaft 7, was excavated from Shaft 8.

The average weekly progress on tunnel excavation westerly was 49.3 feet, the maximum progress being in the week ending January 11, when 64.5 feet were excavated. The contractor's force averaged 96 men. The average number of persons occupying the camp throughout the year was 41, the maximum population being 58 during the week ending February 21.

There was no material change in the plant items during the year, except that the installation of tunnel lining plant was continued as described elsewhere in this report. One more pump was used, making 12 in all on the tunnel construction, the largest having a rated capacity of 1,100 gallons per minute under a 440 foot head, driven by a 200 H. P. motor. The combined compressor capacity continued at 1,532 cubic feet per minute.



CONTRACT 14. — Crusher and Aggregate Piles at the Top of Shaft 2.



CONTRACT 25. — Construction of Outlet Building at Top of Shaft 1, Showing Interior Wall Finish of Tile and Face Brick.

Shaft 8. — (Under the supervision of the Coldbrook-Swift Tunnel Division.) Tunnel excavation was completed on February 6, the length excavated being as follows:

Location	To Nov. 30, 1929	Year ending Nov. 30, 1930	Total
East Heading	3,843 ft.	660 ft.	4,503 ft.
West Heading	4,355 ft.	643 ft.	4,998 ft.
Total	8,198 ft.	1,303 ft.	9,501 ft.

Excavation was stopped in the west heading January 19, 4,355 feet west of the shaft. The east heading was holed through to the west heading of Shaft 7 February 6. The average weekly progress on tunnel excavation westerly was 82.2 feet and easterly, 66.1 feet.

Trimming the side walls and arch and grading the invert preparatory to placing concrete was completed in the west tunnel during the week ending March 22nd, and in the east tunnel during the week ending April 5th.

Work on taking down the head frame was begun on April 21st and completed on May 1st. The sump at the foot of the shaft was then mucked out and lined with concrete up to the bottom of the cast iron shaft lining. The contractor then built a heavy timber platform slightly below this elevation as a protection for those working in the tunnel against work being done in the shaft. This cut off communication with the tunnel by way of Shaft 8 and since that time it has been necessary to use Shaft 7 when entering the tunnel. One 8-inch pipe for pump discharge and two 4-inch pipes, one for air and the other for electric cables, were placed back of the cast iron lining for the contractor's use during construction.

A ten-ton stiff leg derrick was set up close to the shaft on the north side and a movable platform built that would just fit inside the cast iron lining. This platform was suspended from beams spanning the top of the shaft by two cables fastened to crabs on the platform itself.

The cast iron lining was built of plates, furnished under Contract 18, six plates about 3 feet-8 inches high forming a complete ring. Each plate weighed about 1,700 pounds. When delivered they were stored on the spoil pile east of the shaft, from there they were brought to the shaft head, one at a time, on a small flat car, picked up, lowered into the shaft and set by the derrick.

After two rings had been set the movable platform was raised nearly to the top of the top ring and the rings backed up with concrete. The concrete used was mixed in a small gasoline engine-driven mixer placed near the top of the shaft handled to the lining in buckets in batches of about 1 cubic yard and placed by means of a double chute resting on the edge of the top ring, which split the batch and delivered it simultaneously at opposite sides of the ring. When the two rings had been backed up to within a few inches of the top the chute was removed from the shaft and another two rings set. This work of placing the cast iron lining was begun on May 17 and completed on May 31.

On August 18 the contractor started removing the heavy protection platform at the foot of the shaft. He then placed the forms for the concrete plug at the top of the cast iron lining. These forms consisted of a heavy wooden platform hung from I-beams and channels across the top of the shaft by 1-inch steel rods about 40 feet long. On this platform the four nozzle castings, one for each of the four control valves, were set in place. These castings were furnished under Contract 18 and weighed about 14,500 pounds each. They were handled by the same derrick used for setting the lining plates and were set between August 31 and September 3. The concrete plug was cast on September 4 and 5, by chuting it into place from the mixer above referred to.

The concrete in the tunnel sidewalls and arch, and in the invert east of Shaft 8, was placed from the concreting plant at Shaft 7. The invert west of Shaft 8, however, was placed from Shaft 8. The aggregates were mixed at the top of the shaft and dropped through a pipe left temporarily through the concrete plug at the shaft top. This work began on October 3. A gap was left in the sidewalls and arch for the steel bulkhead west of the shaft. This was erected and the gap and central pier concreted when the invert was placed.

All concrete west of Shaft 8 was completed during the week ending November 15.

The contractor's force averaged 38 men throughout the year. The average number of persons occupying the camp to April 7 was 49, the maximum population being 101 during the week ending December 12, 1929. The buildings used for camp purposes were removed by June 6th.

There has been no material change in plant items during the year. The only items of plant in use at this shaft at the end of the year were 7 pumps, the largest of which has a rated capacity of 1,000 gallons per minute under a 275-foot head, driven by a 100 H. P. motor.

The total work done and materials furnished to date under the principal items of Contract 17 were as follows:

Rock excavation in shafts, and in tunnel within 50 ft. of shafts	4,697	cu. yds
Excavation in tunnel except within 50 ft. of shafts . .	250,200	cu. yds.
Shaft and tunnel drainage	34,343	lin. ft.
Forms for preliminary concrete lining, Shaft 8	246	lin. ft.
Forms for concrete lining in tunnel	41,109.5	lin. ft.
Concrete masonry in shafts	1,476	cu. yds.
Concrete masonry in tunnel	85,112	cu. yds.
Concrete masonry not in shafts or tunnel	456	cu. yds.
Permanent timbering in tunnel	1.84	M ft. B. M.
Temporary timbering in tunnel	3.44	M ft. B. M.
Portland Cement	116,095	bbls.
Earth excavation	570	cu. yds.
Rock excavation except in shafts or tunnel	760	cu. yds.
Caring for and setting metal-work furnished by the Commission except Shaft 8 lining	85,095	lbs.
Caring for and setting cast iron lining for Shaft 8 .	508,010	lbs.

Concrete Lining of Tunnel — Contracts 14 and 17: — The contractor used three complete tunnel concrete plants for placing of tunnel concrete sidewalls and arch designated as plants "A", "B", & "C". They were practically identical in design and layout. The first tunnel plant, designated as Plant A and utilizing the aggregate from the crushing plant at the top of Shaft 7, started concreting sidewalls and arch on February 20, 856 feet west of Shaft 6 and continued 8,307 feet westerly to a point 69 feet east of Shaft 7 reaching this point on May 7. At this time the plant was turned around and moved to 31 feet east of the west heading of Shaft 8. It started concreting on May 23 and continued 4,951 feet easterly to 16 feet west of the center line of Shaft 8. On July 5 it passed by the shaft leaving a gap of 31 feet to be built with special forms at the bottom of the shaft, and continued 9,952 feet easterly to 81 feet west of Shaft 7 reaching this point on September 20. The remaining 150 feet of sidewalls and arch adjacent to the shaft, excepting a gap of 22 feet at the bottom of the shaft was concreted at this time. However, due to the cramped quarters the concrete for this length of 128 feet was mixed on the surface, lowered on the cage in a concrete car and delivered by chute to the concrete gun from which it was delivered to the forms.

The plant was then partially dismantled and hauled through the tunnel to the point 2,882 feet west of Shaft 4 to which concreting had previously been completed by Plant B, where it started concreting sidewalls and arch on September 30. utilizing aggregate from the crushing plant at the top of Shaft 4. It continued easterly 2,831 feet to 51 feet west of Shaft 4, reaching this point on October 20. The plant was then turned around and moved to the point 11 feet east of Shaft 3 at which Plant B had previously started concreting easterly. It started concreting on October 25 and continued westerly past the bottom of the shaft, 3,269 feet to the point 3,258 feet west of Shaft 3 at which Plant C had previously started concreting westerly, reaching this point on November 27. The plant then moved ahead to 486 feet east of Shaft 4, where on November 28, it again started concreting sidewalls and arch and continued 360 feet westerly to 126 feet easterly from the center line of Shaft 4.

The second tunnel plant, designated as Plant B and utilizing the aggregate from the crushing plant at the top of Shaft 5, started concreting sidewalls and arch on March 24, at the point 856 feet west of Shaft 6 where Plant A had started westerly, and continued easterly 845 feet to 11 feet west of the center line of Shaft 6. On April 9, it passed by the shaft leaving a gap of 22 feet at the bottom of the shaft and continued 11,079 feet easterly to 12 feet west of the center line of Shaft 5.

The plant was turned around and moved to 3,999 feet east of Shaft 5. It started concreting on July 11 and continued 3,977 feet westerly to 22 feet east of the center line of Shaft 5, reaching this point on August 8. The plant was again turned around and moved back to the point 3,999 feet east of Shaft 5, from which it had concreted westerly. Utilizing the aggregate from the crushing plant at the top of Shaft 4, it started concreting August 13 and continued 4,752 feet easterly to 2,882 feet west of Shaft 4, reaching this point on September 20. The plant was then partially dismantled and hauled through the tunnel to 11 feet east of the center line of Shaft 3. Utilizing the aggregate from the plant at the top of Shaft 2, it started concreting September 26 and continued 8,547 feet easterly, having reached, at the end of the year, a point 609 feet west of Shaft 2.

The third tunnel plant, designated as Plant C and utilizing the aggregate from the crushing plant at the top of Shaft 4, started concreting sidewalls and arch on July 25, 3,258 feet west of Shaft 3 and continued 5,075 feet westerly to 486 feet east of Shaft 4 reaching this point on September 9. The plant was then partially dismantled and hauled through the tunnel to the point 526 feet west of Shaft 1 to which the lining, of circular section, had been completed as described in the report for 1929. Utilizing the aggregate from the crushing plant at the top of Shaft 2, it started concreting on September 14 and continued westerly 9,237 feet to 139 feet east of Shaft 2 reaching this point on November 28.

The following is a summary of the tunnel lengths in which the sidewalls and arch were concreted in various stretches from the three tunnel lining plants. The information given in this table as to average weekly rates of progress supplements that shown in graphical form in the chart appended to this report. The maximum progress in any one week was 1,348 feet of sidewalls and arch concreted from Plant B in the week ending June 21st.

PROGRESS OF ARCH AND SIDEWALL LINING

Aggregate from Crushing Plant at:—	Sidewalls and Arch Concreted From:— Plant A: Total Feet Concreted in one Stretch	Plant A: Average per Week	Plant B: Total Feet Concreted in one Stretch	Plant B: Average per Week	Plant C: Total Feet Concreted in one Stretch	Plant C: Average per Week	Feet of Shaft Bottoms Concreted from Mixer on Surface	Total Feet Concreted
Shaft 2			8,547.	920.5	9,237.	862.2		17,784.
Shaft 4	2,831. 3,269. 360.	990.8 693.4 840.0	4,752.	875.3	5,075.	772.3		16,287.
Shaft 5			11,079. 3,977.	834.7 994.2				15,056.
Shaft 6							22.	22.
Shaft 7	8,307. 4,951. 9,952.	765.1 876.4	845.				128.	24,183.
Shaft 8							31.	31.
Total Side Walls & Arch of Horseshoe Type Section, for Year Ending 11-30-30	29,670.		29,200.		14,312.		181.	73,363.
Total to Nov. 30, 1929. Shaft 1, circular section (includes 11 feet at the shaft) . .								526.
Total Completed, to Nov. 30, 1930 . .								73,889.
Remainder Uncompleted 11-30-30								981.
Total Length under Contracts 14 and 17								74,870.

The lining of tunnel invert was carried on from the same shafts as were previously used for the lining of the side walls and arch except that concrete for the invert west of Shaft 8 was mixed outside the foundation walls of the Ware River Intake Works and chuted to the bottom of the tunnel through a temporary pipe left through the concrete plug which supports the control valves at the top of the shaft. The placing of invert was started on August 16, from the mixing plant at the top of Shaft 5. Starting 64 feet east of the center line of Shaft 6, the work progressed 11,024 feet easterly to 14 feet west of the center line of Shaft 5, reaching this point November 19; and starting October 30, 5,806 feet east of Shaft 5, the work progressed westerly 5,782 feet to 24 feet east of the center line of the shaft, reaching this point on November 20. From the mixing plant at the top of Shaft 7 the placing of invert was started October 13, 62 feet west of the center line of Shaft 6 and progressed 8,857 feet westerly to 313 feet east of Shaft 7, reaching this point November 13. The remaining gap of 126 feet in the invert at the bottom of Shaft 6 was completed in November. West of Shaft 8, using concrete chuted from the top of the shaft as previously described, the work began October 1, 31 feet east of the west heading of Shaft 8 and progressed 4,951 feet easterly to 16 feet west of the center line of the shaft reaching this point November 9th. Invert was then started 15 feet east of the center line of Shaft 8 and, using the mixing plant at the top of Shaft 7, continued easterly, 2,731 feet, at the end of the year reaching a point 2,746 feet east of Shaft 8.

The placing of invert from the mixing plant at the top of Shaft 4 was begun November 27 at the end of the previously completed invert 5,796 feet east of Shaft 5. The work had progressed 1,049 feet easterly at the end of the year.

The following summary of progress in invert lining supplements the data shown in graphic form on the chart appended to this report. The maximum progress in any one week was 2,385 feet of invert concreted from Shaft 5 during the week ending November 15, 1930.

PROGRESS OF INVERT LINING

Aggregate from Crushing Plant at	Total feet Concreted in one Stretch	Average No of Feet Per Day
Shaft 4	1,049.	262.
Shaft 5	11,024.	115.
	5,782.	264.
Shaft 7	8,857.	277.
	126.	
	2,731.	171.
Shaft 8	4,951.	124.
Total Invert During Year of 1930	34,520.	
Total to 11-30-29 Shaft No. 1 circular section (includes 11 ft. at the shaft)	526.	
Total Completed to Nov. 30, 1930	35,046.	
Remainder Uncompleted 11-30-30	39,824.	
Total Length Under Contracts 14 and 17	74,870.	

Four crushing and screening plants were used. These, in order of their use, were at Shafts 7, 5, 4 and 2, the latter plant being constructed largely of dismantled plant from Shaft 5. Rock from the tunnel spoil banks was used to obtain concrete aggregates for the tunnel lining.

Crushing. — Each crushing plant consisted essentially of:

1. A 1½ cubic yard dragline scraper, equipped with a 75 H. P. motor, which operated over the spoil bank and brought the material to a grizzly, constructed of rails placed about 12 inches on centers, and which made an initial separation of rocks too large for handling by the primary crusher. These rocks, while still on the grizzly, were broken into smaller sizes by a striking hammer, so that all material brought by the scraper eventually went by way of a short conveyor belt or apron feeder to a 5-foot diameter by 8-foot primary crusher screen containing 4-inch openings.

2. A 12-inch gyratory crusher taking the material rejected by the primary crusher screen. The jaws of this crusher were adjusted so that the resulting product could be easily handled by the secondary crusher. The product of this

crusher was directed through a chute to a 24-inch conveyor belt and conveyed, together with the material that had previously passed through the primary screen, to

3. A steel rotary sizing screen, 5 feet in diameter and 18 feet long, made up of 8 feet of screen with 2-inch perforations and 10 feet of screen with ¾-inch perforations outside of which was a dust jacket of ¼-inch mesh screening, which separated the material into sizes, that below ¼-inch being used as fine aggregate and between ¼-inch and 2-inch as coarse aggregate. Rock particles which failed to pass through the 2-inch screen were rejected into

4. A secondary cone crusher which reduced these to smaller sizes, the resulting products being conveyed by a return belt to the main 24-inch conveyor belt, where they were again brought to the secondary screen. At Shaft 4, 36-inch rolls were installed which manufactured fine aggregate from the material passing the ¾-inch screen, the output being conveyed by a return belt to the secondary screen for further separation.

5. A system of chutes, under the secondary screen, which directed the final crushed product to two conveyor belts extended to the two stock piles, one for fine aggregate, the other for coarse aggregate.

6. To prevent metallic material from reaching the secondary screen and crusher, an electric magnet was suspended over the conveyor belt extending from the primary crusher and screen.

During the early period of operation of the first crushing plant, at Shaft 7, a difficulty arose in the proper separation of the aggregates. Moisture and frost in the spoil bank caused considerable quantities of fine material to pass along with the coarse aggregate, resulting in a variable product. This difficulty was overcome to the extent required by the installation, within the secondary screen, of four open flame oil burners. Similar installations were made at other plants.

The elimination of excessively fine particles in the fine aggregate at Shafts 4 and 5 was accomplished to the extent required by air from a 12-inch blower directed against the sand stream from the end of the conveyor belt over the storage pile. The dust was blown into a metal hood from which it was carried in a metal pipe line clear of the stock pile by water.

Batching. — The batching of aggregates was done in a heavy timbered trap tunnel, 5 feet square in section and about 130 feet long, over which the fine and coarse aggregate was stocked. Within this tunnel, under the centers of the two stock pile cones, were located two weighing hoppers or batchers equipped with sliding gates at the bottom and top. In weighing the proper amounts of aggregate for a 1-cubic yard batch the upper gate was opened (the lower being shut), and closed when the proper weight was indicated. When the signal for a batch was given the lower gate was opened and the coarse aggregate discharged on to a 16-inch conveyor belt under the hopper which extended through the trap tunnel to the top of the shaft. As soon as the coarse aggregate was strung out on the belt for a distance of about 50 feet the fine aggregate was similarly weighed and discharged, the cement was deposited, and the whole conveyed to and dropped through an 8-inch pipe to a hopper, at the base of the shaft. The cement was fed from a cement hopper located in the cement shed, which consisted of a 4-foot square table constructed directly over the belt and having a recess in the center equipped with a sliding gate in the bottom and capable of handling six bags of cement. This hopper was generally located over the belt from the trap tunnel, but where this was impracticable the cement was carried by a shorter belt to the main conveyor belt.

Each batch was discharged from the hopper at the bottom of the shaft into one compartment of a 2-compartment bottom dumping car. A 5-car train was made up in this manner and hauled by a storage battery locomotive to the mixer, which was located near the forms. Three such trains, working in conjunction with each tunnel concreting plant, were ordinarily used, one being loaded, one traveling, and one feeding the mixer, only two motors, however, being required, except for long hauls where a passing siding was sometimes installed.

Mixing and Placing Concrete. — On the shaft side of the mixer was located a portable inclined double track with switch at either end, mounted on wheels which ran upon the tracks in the tunnel invert. The loaded train of aggregate was pushed on to this portable track, and when this was accomplished the motor was disconnected from the train. The empty cars on the other track were then taken back to the shaft by the same motor which had brought the loaded cars to the mixer. The loaded car nearest the mixer was uncoupled and pulled by a small air tugger hoist up a short but steeper incline to a point over a 20-inch conveyor belt which led to the charging side of the mixer. At this point the contents of one compartment were dumped and conveyed to the mixer, where they were tempered with the necessary amount of water, mixed, and discharged into the concrete gun. After both batches had been discharged from a car, it was moved by gravity by means of a spring switch to the parallel track reserved for empty cars. This operation was repeated until all five cars were empty, and when another loaded train arrived at the mixer the empty cars were hauled back to the shaft for another load.

The mixer used was a 1-cubic yard non-tilting type driven by an air engine. The gun had a 32-inch bore and capacity for 1 cubic yard. It was equipped with a piston operating through a 5½-foot stroke which forced the concrete into a 6-inch chuting line and out over the forms. Air pressure of from 75 to 100 pounds was required for satisfactory operation. The mixer and gun were both mounted on trucks and together with the portable incline supporting the two tracks were moved as a unit.

Under ordinary conditions the total length of the chuting line was 125 feet, the first 25 feet, which was level, being made up of four 6-foot 3-inch lengths fitted with quick-acting self-sealing couplings. The pipe then made a 22½-degree vertical bend, followed along a traveler for 30 feet, and then after another 22½-degree vertical bend continued level over the top of the forms. The sections on the traveler and forms were made up of 20 and 10-foot lengths, fitted with sleeve couplings. These sections were removed only when replacement was necessary. All bends were of manganese steel. As the concrete filled behind the forms and reached the nozzle end of the chuting line, a move back was made by removing one of the 6-foot 3-inch lengths and drawing the traveler and chuting line back, the pipe sliding along on top of the forms. When all four of these lengths had been removed, the rig, gun and mixer were moved back, the four lengths replaced, and operations continued.

Forms. — With each of the three plants were used 200 feet of steel collapsible forms divided into eight 25-foot sections, each section being made up of five 5-foot panels. A door was provided in each arch panel which permitted access to the top of the form. Through these doors the placing of the concrete was watched and the chuting line moved as conditions might warrant. As the forms filled, these doors were closed and securely bolted. The sections of forms were hinged at the center of the arch and at a point 30 inches from the bottom of each side wall. When in place the forms were set on 3-inch by 10-inch wooden sills which were set to line and grade and usually carried 500 to 600 feet in advance. All three hinge joints were bolted and the forms braced with trench jacks clamped between the bottom of the form and the track ties, eight jacks being used on each side of each 25-foot section of form, each pair catching the same tie. This was the only bracing required. When a section of form was to be moved, a form jumbo equipped with two center jacks and four side turnbuckles was run under it, all the hinges freed and the braces removed. The jacks on the jumbo were then raised to catch the form in the center. The 30-inch section at the bottom of each side was then raised with chain falls and these together with the sides drawn inward by turnbuckles. The jacks then lowered the section and a small air tugger attached to the pipe traveler telescoped the form through to the end of the other section where it was set in place under the chuting line. Only the sidewalls and arch concrete were placed by this method, the work being carried on as one continuous pour by three crews each working eight hours.

Laboratory Control of Concrete. — Concrete aggregates were batched by weight,

and at least once daily, and sometimes more frequently, determinations were made of the free moisture contained in the sand and stone.

Complete analyses of fine aggregates were made from time to time to determine the size of particles and daily determinations were made of the admixture of fine and coarse aggregates in their respective cones, the separation being obtained on a screen with approximately ¼″ openings. These variables having been determined for the day, the scale weights were set for the correct weight of fine and coarse aggregates. The net amount of water to be added was obtained by subtracting the total free water in the sand and stone from the gross amount required. Control of the quality of tunnel concrete also was obtained in frequent slump and strength tests.

Placing of Invert Concrete. — The same crushing plants as above described were used to produce aggregates for invert concrete. The concrete was mixed on the surface in a one-yard mixer, which required a rearrangement of plant near the shaft head. Four blow torches were used to heat the mixer as required during the winter months. The mixer was placed at an elevation above the service track at the top of the shaft such that the concrete could be discharged into V-bottomed steel muck cars reconstructed especially for this purpose. They were lowered on the cage one at a time and a train of 6 or 8 loaded cars was hauled to the point of concreting by a storage battery locomotive.

A night shift prepared the tunnel for concrete and a day shift mixed and placed the concrete. The night shift graded the bottom, did necessary ditching, built stone and box drains where needed, removed track and piping no longer required, and did general cleaning up. The concrete cars were so spaced when coupled together in a train that each car contained as nearly as possible the quantity required to complete the invert opposite the car. Water in the tunnel was pumped over low sand bag dikes at either end of the section being concreted, the tracks being raised to pass over the dikes. The concrete was spread by hand, shoveled and screeded by hand using a wood screed with metal edge working between steel templates made of a T-section bent to the curve of the invert spaced 10 feet on centers and held by set screws against the sidewalls. The templates were removed and the adjacent invert completed when the concrete began to set. Access to points over freshly laid concrete was had by narrow plank walks supported on timbers wedged between the sidewalls. Roofing paper was spread over the freshly laid concrete when required to protect it from water dripping from the roof or sidewalls. Where required, broken stone or box drains were extended to points where the drainage could be conveniently vented through the invert and transverse concrete cut-off walls to rock were built frequently to force the discharge of box drains through the invert.

The principal items of plant equipment used in the tunnel lining operations were as follows:

For one Plant	Total for All Plants	Description
		Crushing Plant
1	3	1½-cu. yd. drag scraper bucket and electric hoist with 75 H.P. motor.
1	3	Apron feeder with drives.
1	3	60″ rotary screen, 8′ long with 4″ perforations.
1	3	60″ rotary screen, 18′ long, 10′ with ¾″ perforations and with ¼″ dust jacket, 8′ with 2″ perforations.
1	3	36″ coarse cone crusher.
1	3	12″ gyratory crusher.
1	3	24″ separator magnet.
4	13	16″ belt conveyors.
1	3	24″ belt conveyor.
1	4	Trap tunnel, bins, stone weighing hopper, sand weighing hopper and platform scale.
		Tunnel Plant
1	3	Aggregate chute and hopper, equipped with air operated sliding gate.
16	53	2-Compartment hopper cars; 84 cu. ft. capacity, 36″ gauge.
3	9	36″ gauge electric storage battery locomotive. (Some additional locomotives previously listed under excavation plant were used in concreting.)

1	3	Portable track and incline rig.
1	3	Portable mixing plant and 9 H.P. tugger hoist, 20″ belt conveyor, 1-cu. yd. non-tilting mixer air engine driven, concrete gun 32″ diameter and 6″ chuting line.
200	600	Linear feet telescoping forms in 25-ft. sections.
1	3	25 ft. long traveler for moving forms.
1	3	10 H.P. tugger hoist.
1	3	Motor generator set.
		Invert Plant
1	2	Motor driven 1 cu. yd. non-tilting mixer on skids, with water tank, feed chute and 220-volt, 3-phase 60-cycle A.C. motor.
8	16	1-cu. yd. steel concrete cars.

Contract 25. — Contract 25, for constructing the superstructure of the Wachusett Outlet Building for the Wachusett-Coldbrook Tunnel at Shaft 1 in the town of West Boylston, was executed on July 23, with Munroe & Westcott, Inc., of North Attleboro, Mass.

Erection work at the site was started September 5. Operations were carried on from a temporary plank floor over the waterway channel. During the year the structural steel frame of the building was practically completed. The building walls of ashlar masonry outside and tile and face brick inside were carried up together as far as the tops of the window arches. Doors, window frames and electric conduits and panels were built in as the work progressed. The stone facing of the south abutment of the dam across the Quinapoxet River was carried up to the bottom of the coping and the bottom course of the north abutment was placed.

At the end of the year the contract was about 25 per cent completed. The contractor's force averaged 13 men. The value of work included in contract estimates to November 10, the date of the latest estimate, was $15,565.58, of which 90 per cent has been approved for payment.

Contract 26. — Contract 26, for furnishing and installing power and lighting wiring and electrical equipment at the Wachusett Outlet Building of the Wachusett-Coldbrook Tunnel at Shaft 1 in the town of West Boylston, was executed on September 24th, with Anderson-Coffey Co., Inc., of Boston. As the building construction progressed, all necessary conduit boxes, fixtures and wall panel boxes were placed. The wiring for lights in the pump shaft was begun on November 14, and practically completed during the year, using a boatswain's chair suspended by a steel cable and operated by a hand winch. The contractor's force averaged one man. No estimates for payment were made before November 30th.

Coldbrook-Swift Tunnel Division — Hardwick Office

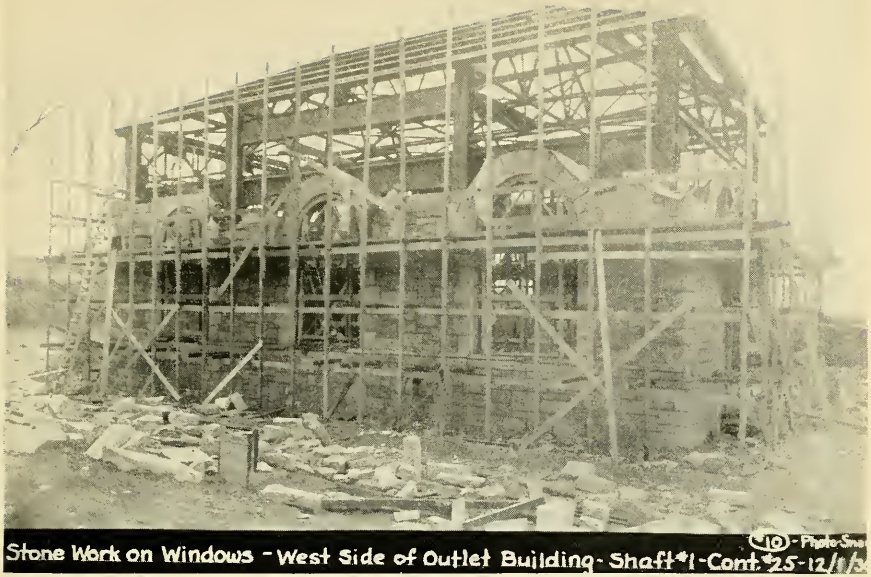
The Coldbrook-Swift Tunnel Division continued in charge of the field work in connection with the proposed Coldbrook-Swift Tunnel extension to the Swift River and of the construction at Shaft 8 of the Wachusett-Coldbrook Tunnel included in Contract 17 and previously described. It also continued in charge of the construction of the low diversion dam and the Ware River Intake Works at Shaft 8 included in Contract 19, and had charge of improvements in the Ware River Watershed.

Office Work

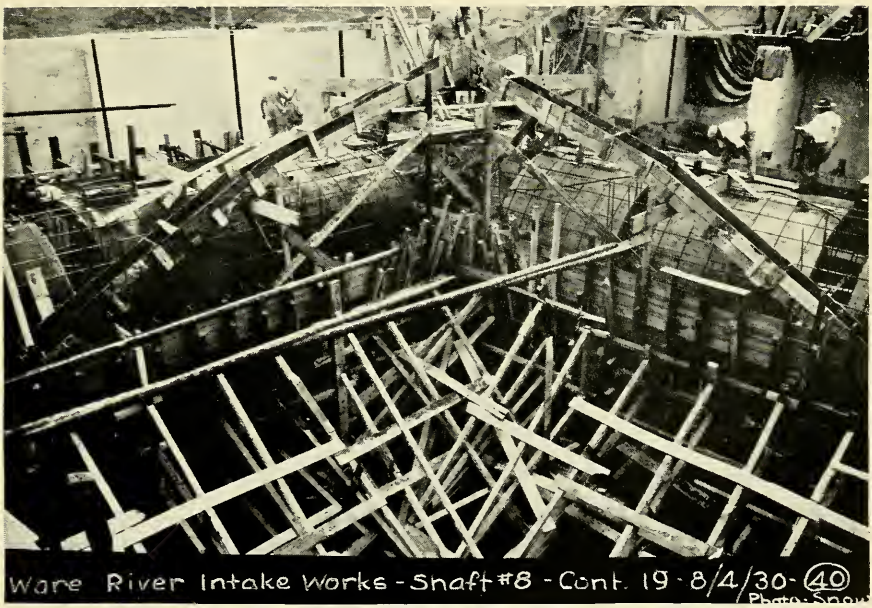
Semi-monthly estimates were prepared for Contract 17 and monthly estimates for Contracts 19, 24 and 27. Plans were made of real estate proposed to be acquired in the upper Ware River Watershed. Topographic maps were made of spoil piles and other areas in the vicinity of Shaft 8. Work was continued on maps and capacity curves of various ponds on the watershed. Daily rainfall records were continued at the White Valley meteorological station.

Field Work

Lines and grades were given for construction work on Contracts 17, 19, 24 and 27. About 465 acres of topography were taken along the Ware River above the intake and in the vicinity of Shaft 8. Mud soundings were made in the Ware River and four ponds in the watershed. A base line for triangulation



CONTRACT 25. — Construction of Outlet Building at Top of Shaft 1, Showing Steel Framework and Random Ashlar Masonry Walls.



CONTRACT 19. — Forms of Siphon Spillways at Ware River Intake Works.

of the Ware River Valley Watershed was established and the triangulation completed. Real estate surveys were made of various properties, including about 850 acres in the watershed. Weekly observations of water color samples along the Ware River and its tributaries were made. Photographs of the construction work were continued. Current meters were repaired and rated from time to time as required. Electrical determinations of the depth to bedrock on the line of the proposed Coldbrook-Swift Tunnel in the vicinity of Muddy Brook were supervised.

Collection of Stream Flow and Water Power Data

Staff gages, set to determine the head at various water power plants on the Ware, Swift, and Chicopee Rivers, were read. Observations to determine the fluctuations in level of the ponds on the Ware and Quaboag River watershed were taken. The recording gages at the gaging stations at White Valley and Bircham Bend were continued.

Investigations of the quality of the water in the Ware River above Coldbrook and from South Barre to Thorndike were continued in conjunction with the laboratory, the principal work of this office being the determination of the necessary hydraulic data.

Construction by Force Account

Work on watershed improvement was done by force account with labor employed and supervised by the division office. Commencing August 25, four small ponds on a tributary of the Ware River in the village of Coldbrook, Whiting Pond, Basket Shop Pond, Grist Mill Pond, and Potter's Pond, were drained and their dams breached. Ditches were then dug in the bottoms of these ponds and dead brush cut and burned on the site of Potter's Pond. A new 15″ concrete pipe culvert was laid under the state highway to drain a portion of Grist Mill Pond and other miscellaneous work of sanitary improvements in the watershed and of repairs to buildings of the Commission was done by force account. From two to six laborers were employed from time to time during the last three months of the year.

Progress of Contracts

The construction work on the Wachusett-Coldbrook Tunnel from Shaft 8 was supervised from the Hardwick Office and is hereinbefore described.

Contract 18. — Contract 18, for furnishing iron castings for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel in the town of Barre, was completed and a final estimate made on January 11, 1930, the total value being $19,431.07.

Materials furnished under the principal items were as follows:

Shaft lining plates	252.387	tons
Nozzle castings	24.57	tons
Base castings	11.14	tons

Contract 19. — Contract 19, for constructing the low diversion dam and the substructure of the Intake Building for the Ware River Intake Works at Shaft 8 of the Wachusett-Coldbrook Tunnel in the town of Barre was continued in force throughout the year. On December 7 the contractor cut the flume which had carried the river past the dam site and continued the construction of the dam across the gap using pumps to keep the water level below the masonry until the water was high enough to flow through the bypass sluice gate.

Masonry work was continued in the dam until December 16 by heating the mixing water, aggregates, and the concrete and stones after placing, the dam being carried up to elevation 644.8. The contractor then removed the flume downstream from the dam and continued until January 7 with a small force, removing and burning stumps and loose timber above the dam. Work was resumed on April 14, and on June 2 the construction forms for siphon spillways and building foundation walls at the top of the shaft were begun. The first concrete in the siphon spillways was poured on June 19 and this was completed and stop planks set on the spillway crests on August 20. Work was resumed on the dam on August 9th.

The use of the aggremeter for proportioning concrete was continued until August 31st, the small remaining amount of concrete being mixed in small portable mixers. On September 5 work was started on setting the valve base castings furnished under Contract 18 and setting the four control valves furnished by the Commission. These valves are of the Dow-disc type, three of them being 60″ in diameter and one 72″ in diameter, above which was installed a 120″ x 60″ Venturi meter. These castings, the largest of which weighed about 12,000 pounds, were handled by the stiff leg derrick used on Contract 17. Their setting was completed September 20, after which work on floor forms progressed rapidly. The beams and floor slabs of the main floor were cast in one continuous operation on October 6 using two small portable mixers, the concrete being left 2″ low to allow for the granolithic finish to be placed later under Contract 24. Early in September the lower weir wall between dam abutments was completed together with riprap and grading in the river bed. A small steam shovel with caterpillar traction was used in this work, and subsequently to remove the spoil piles which were placed in the earth portion of the dam, in grading below the dam and around the intake building and in filling the old canal east of the building. Impervious core in the earth portion of the dam was built up slightly ahead of the rest of the embankment. For this core and for dressing of slopes, top soil was excavated by hand from a borrow pit on high ground north of the shaft, transported in small trucks and spread and rolled by hand. Two small steam shovels were used to remove the old White Brothers dam which was breached on October 1. One shovel worked on the north side placing the materials in the old canal, the other on the south side placing the materials in the old spillway channel. Stumps, logs and other debris were removed from the bed of the stream between the old dam and the state highway bridge at Coldbrook. At the end of the year this contract was completed except for miscellaneous small items of work, and the principal items of the Contractor's plant were removed.

Except timber which was hauled by truck, nearly all materials including cement, concrete aggregates, stone and steel were delivered by rail on the contractor's siding. Granite for stone masonry was furnished from quarries in Fitchburg.

The value of work included in contract estimates to November 15, the date of the latest estimate, was $252,679.21, of which 90 per cent was approved for payment.

The contractor's force averaged 34 men for 39 weeks, the maximum force during any one week being 87 men for the week ending August 9, and the average throughout the year being 26. The total work done and materials furnished to November 15 under the principal items of Contract 19 were as follows:

Earth Excavation (below elevation 642)	4,280	cu. yds.
Earth Excavation (above elevation 642)	3,000	cu. yds.
Rock Excavation	1,928	cu. yds.
Earth Filling and Embanking of Pervious Material	5,683	cu. yds.
Riprap	915	cu. yds.
Portland Cement	9,958	bbls.
Concrete Masonry	6,534	cu. yds.
Dimension Stone Masonry	120	cu. yds.
Ashlar Masonry	524	cu. yds.
Steel for Reinforcing Concrete	202,000	lbs.

Contract 24. — Contract 24, for constructing the superstructure of the Intake Building for the Ware River Intake Works at Shaft 8 of the Wachusett-Coldbrook Tunnel in the town of Barre, was executed on July 23, with Munroe & Westcott, Inc., of North Attleboro, Mass.

Work was begun October 9 and a derrick was set up during the week ending October 18. Erection of structural steel frame work was practically completed November 22. At the end of the year the steel work was partly riveted and the stone facing of the foundation walls placed up to elevation 665. The value of the work included in contract estimates to November 15, the date of the latest estimate, was $8,395.11 of which 90 per cent was approved for payment.

The contractor's force averaged 6 men for 8 weeks, the maximum force during any one week being 13 men during the week ending November 15.

Contract 19. — Ware River Intake Works View from Upstream of the Diversion Dam and Siphon Spillway Intakes.
Contract 24. — Steel Framework of Superstructure.

Contract 19. — Remains of Old White Valley Dam on Bed of Ware River Above the Intake Works.
Contract 17. — Tunnel Spoil Banks on Either Side of River.

Contract 27. — Contract 27, for filling with earth areas along the bank of the Ware River in the town of Barre, was executed on September 23 with Raymond A. Bergesson of Sagamore, Mass.

Work started October 20 with the cutting and burning of brush on the area to be filled and at the borrow pit. Placing of fill was started October 30. A gasoline shovel and 6 trucks were used. At the end of the year the work was about 90 per cent complete and the value of work included in contract estimates to November 10, the date of the latest estimate, was $1,450.00, of which 90 per cent was approved for payment.

The contractor's force averaged 7 men for 6 weeks, the maximum force being 10 during the week ending November 15.

Swift River Reservoir Division — Enfield Office

The Swift River Reservoir Division continued in charge of the field work in the Swift River Valley in connection with the proposed Swift River Reservoir.

The major activities of this division continued to be topographic surveys of the proposed reservoir basin, general surveys of real estate required for reservoir purposes, preparation of maps of all surveys, cemetery removal work and studies of soils and other materials with reference to the possibility of their use in the construction of the proposed dam and dike.

Topography. — During the year 1,040 acres of topography within and adjacent to the proposed reservoir were surveyed, making a total to date of 23,815 acres, or 37.21 square miles. During the year 980 acres of topography were mapped, making the total to date 23,580 acres. Of this total tracings have been made covering 19,565 acres. In the vicinity of the proposed dam site topography has been replotted and traced to meet the requirements of the designing division. Surveys were made of the profile of the Boston & Albany Railroad traversing the proposed reservoir area and of cross sections of the Swift River downstream from the proposed dam site. Three hundred fifty acres of topography were taken and plotted during the year in connection with studies of highway and railroad relocation.

Real Estate. — Property described in applications by owners for sale of real estate was located and sketches made showing the approximate location. Additional property purchased by the Commission during the year, as the deeds were received in the Enfield office, was plotted on the general property map with a scale 1 inch=1,000 feet. Comprehensive real estate surveys and analyses, and descriptions of deeds were continued. Practically all land within one-half mile of the proposed reservoir has been surveyed and tables compiled showing the ownership, area and valuation of properties not yet offered for sale by the owners. The real estate surveys during the year cover 4,890 acres, making a total to date of 57,390 acres, or 89.67 square miles. Of this total 56.605 acres have been plotted at a scale of 1 inch=200 feet. About 200 acres of land were cruised by standard forestry methods.

Photography. — The photographing of buildings and cemetery lots continued. Photographs of practically all buildings lying within the area to be affected by the proposed reservoir have been taken and record prints made. During the year 352 photographs of buildings, 561 of cemetery lots and 289 of the progress of construction carried on under the supervision of other divisions, were taken by this division.

Cemeteries. — No general removal of bodies from within the proposed reservoir has been undertaken, but removals at the request of interested parties continued. During the year 37 releases of rights in cemetery lots were executed by interested parties and all work of removal completed under the supervision of this division with labor engaged directly for this work. During the year 149 bodies were removed from 59½ lots in various cemeteries in the area to be affected by the reservoir, together with 71 headstones and 28 monuments, making a total removed to date of 401 bodies, 170 headstones and 69 monuments.

Soil Testing. — The soil testing laboratory was continued in the office basement until the middle of May when equipment was moved to the first floor of the

Barlow House, so called, which had been purchased by the Commission and remodeled for laboratory use. New equipment was purchased to provide small can percolation tests, capillary tube tests, specific gravity tests and grain size analyses.

Tests of the permeability and other characteristics of soils were continued. Samples of materials from the sites of possible borrow pits for the dam and dike embankments were collected and tested. For this purpose test trenches were dug to a depth of about 5 feet by labor employed on force account. Post hole augers were used to determine the depth and extent of deposits of various materials.

Chemical and Bacteriological Laboratory. — Following the moving of the Springfield Laboratory to Enfield, its work of collecting and analyzing water samples and preparing records and reports was continued in cooperation with the headquarters office and with assistance from the Coldbrook-Swift Tunnel Division.

Fire Protection. — The fire fighting equipment housed at Enfield has been maintained in readiness for service at all times. Five assistants in the division office were reappointed as deputy forest wardens in each of the towns affected by the reservoir. The equipment and personnel responded during the year to calls for assistance at 19 forest fires which burned over a total area of 152 acres. The apparatus also responded to fires in 14 buildings.

Hydrographic Data. — Records of rainfall and daily maximum and minimum thermometer readings were kept at the division office throughout the year. This office has also cooperated with the headquarters office in other hydrographic work.

Blister Rust Control. — This office continued to supply labor for cooperative work with the State Department of Agriculture's Bureau of Plant Industry, for the eradication of current and gooseberry bushes for the control of pine blister rust in that portion of the Swift River Valley above the proposed reservoir flow line. The area covered in the cruises for eradication was about 10,500 acres in eight towns.

Contract 23. — Contract 23. for making borings in the towns of Belchertown, Enfield, Ware, Greenwich, and Hardwick continued in force throughout the year. Explorations were made for location of bedrock, depth of overburden and occurrence of material suitable for construction purposes, in the vicinity of the tunnel portal in the town of Greenwich, the proposed main dam and spillway in the towns of Enfield and Belchertown, and the proposed dike site in the town of Enfield.

The total value of work included in contract estimates to November 10, the date of the latest estimate, was $10,441.58, of which 90 per cent has been approved for payment.

The contractor has had one drilling rig in operation during the year and employed an average of two men.

The total work done under the principal items was as follows:

Wash borings — 845.09 linear feet.
Core borings to surface of sound bedrock — 1723.95 linear feet.
Core borings in sound bedrock — 793.11 linear feet.
Casings ordered left in place — 272.37 linear feet.

Geological Data

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State." Such information has been published in previous reports and a complete report of the geology of the Wachusett-Coldbrook Tunnel is now in preparation for publication in a subsequent report.

List of Drawings and Tables Appended Hereto

Chart — Progress of Construction — Wachusett–Coldbrook Tunnel.
Location of Real Estate Acquired for the Swift River Reservoir.
Real Estate Takings.
Status of Contracts completed prior to November 30, 1929.

Status of Contracts in force between November 30, 1929, and November 30, 1930.
Total Value of Work accomplished under Contracts in Progress during year ending November 30, 1930 — Shown Monthly.
Canvass of Bids, Contract 24.
Canvass of Bids, Contract 25.
Canvass of Bids, Contract 26.
Canvass of Bids, Contract 27.

For General Plan of Metropolitan Water Supply and Profile of Wachusett-Coldbrook Tunnel, see Second Annual Report.

Respectfully submitted,

FRANK E. WINSOR,
Chief Engineer.

24 SCHOOL STREET, BOSTON, MASS.
December 15, 1930.

Financial Statement of the Metropolitan District Water Supply Commission

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

Administration — (Commissioners' Office):

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
Salaries, Commissioners	$10,500.00	$45,612.80
Salaries, Clerical	10,364.96	38,685.63
General Legal Expense	0.50	1,377.80
Furniture and Fixtures	58.27	1,952.58
Rent and Upkeep	3,169.93	9,232.69
Automobile Purchase	584.90	1,988.90
Automobile Maintenance	318.54	1,277.56
Miscellaneous Expense (undistributed)	2,244.33	7,645.10
Advertising	790.84	2,944.82
Printing and Blueprinting	666.62	2,782.21
Stationery and Office Supplies	247.97	833.18
Postage	110.86	360.55
Total Administration	$29,057.72	$114,693.82

Engineering, Headquarters Office:

Salaries, Engineering	$81,992.08	$315,146.99
Salaries, Clerical	10,318.44	37,138.55
General Consultant Expense	47,152.28	89,697.69
General Legal Expense	15,934.34	16,179.03
Furniture and Fixtures	423.16	11,174.89
Laboratory Equipment	404.54	1,961.00
Laboratory Supplies	139.45	2,071.94
Rental of Equipment	508.26	3,370.02
Engineering Instruments	785.68	849.22
Rent and Upkeep of Boston Office	9,453.74	40,555.07
Rent and Upkeep of Springfield Laboratory	1,604.51	3,950.54
Automobile Purchase	584.90	2,675.60
Automobile Maintenance	540.58	2,166.57
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	4,584.01	16,105.12
Printing and Blueprinting	4,095.34	8,202.91
Stationery and Office Supplies	853.05	2,326.20
Postage	232.25	654.58
Total Engineering, Headquarters Office	$179,606.61	$556,530.55

Unassigned:

Unassigned Supplies and Equipment	—$361.67	$645.24
Total Unassigned	—$361.67	$645.24
Total General Overhead	$208,302.66	$671,869.61

Distribution of General Overhead

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
Administration:		
Wachusett-Coldbrook Tunnel Division	$15,362.21	$49,959.29
Coldbrook-Swift Tunnel Division	1,921.93	7,353.50
Swift River Reservoir Division	11,760.54	48,713.27
Southern Sudbury Emergency Supply	13.04	8,667.76
Total Administration	$29,057.72	$114,693.82
Engineering, Headquarters Office:		
Wachusett-Coldbrook Tunnel Division	$65,171.33	$204,528.04
Coldbrook-Swift Tunnel Division	6,327.03	32,924.71
Swift River Reservoir Division	108,014.49	285,680.77
Southern Sudbury Emergency Supply	93.76	33,397.03
Total Engineering, Headquarters Office	$179,606.61	$556,530.55
Wachusett-Coldbrook Tunnel Division		
General Overhead:		
Administration	$15,362.21	$49,959.29
Engineering	65,171.33	204,528.04
Total General Overhead	$80,533.54	$254,487.33
Engineering:		
Salaries, Engineering and Clerical	$109,305.13	$304,748.98
Consultant Expense	833.37	4,354.62
Furniture and Fixtures	177.05	1,664.36
Engineering Instruments	655.66	8,042.60
Rent and Upkeep	2,181.34	8,272.52
Automobile Purchase	1,625.26	8,443.47
Automobile Maintenance	2,649.24	10,017.63
Contracts for Investigations and Surveys	0.00	16,075.11
Miscellaneous Expense (undistributed)	2,005.32	6,145.38
Advertising	0.00	6.05
Printing and Blueprinting	190.80	723.19
Stationery and Office Supplies	306.94	1,925.54
Postage	32.86	244.85
Total Engineering	$119,962.97	$370,664.30
Real Estate (General Construction):		
Legal and Expert Expense	$176.39	$4,177.41
Consultant Expense	0.00	394.40
Labor	0.00	906.55
Miscellaneous Expense	41.81	283.05
Purchase and Settlements	8,150.00	115,089.71
Taxes	0.00	2,037.98
Maintenance of Real Estate	93.20	311.59
Police Protection, Labor	5.00	20.00
Fire Protection	30.97	30.97
Special Agents Salaries	2,370.00	5,763.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	308.00	903.50
Automobile Maintenance	452.85	1,182.66
Miscellaneous Expense (undistributed)	200.01	638.97
Printing	0.00	7.89
Postage	4.00	4.36
Total Real Estate	$11,832.23	$131,869.71

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
WARE WATERSHED PROTECTION:		
Salaries, Engineering	$10,208.12	$12,937.64
Clerical	15.34	15.34
Legal and Expert Expense	2,517.63	6,436.55
Consultant Expense	0.00	763.70
Labor	1,392.55	3,437.55
Contracts	1,305.00	1,305.00
Miscellaneous Expense	134.40	322.64
Printing and Blueprinting	144.83	166.87
Purchases and Settlements	53,208.78	473,555.15
Taxes	2,849.64	5,858.30
Total Ware Watershed Protection	$71,776.29	$504,798.74
WARE DIVERSION DAMAGES:		
Salaries, Engineering and Clerical	$7,486.33	$20,403.06
Legal and Expert Expense	9.28	9.28
Consultant Expense	483.22	2,426.39
Labor	13.40	33.02
Miscellaneous Expense (undistributed)	445.41	3,270.29
Printing and Blueprinting	7.99	75.54
Postage	0.00	.75
Engineering Instruments	0.00	45.08
Laboratory Equipment	21.43	58.57
Laboratory Supplies	0.00	27.88
Rental of Equipment	42.00	78.25
Contracts for Investigations and Surveys	0.00	63.27
Total Ware Diversion Damages	$8,509.06	$26,491.38
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 4, Sinking Shaft 5 and driving 1,367 linear feet of tunnel	$0.00	$290,581.99
Contract No. 8, Sinking Shafts 6 and 7 and driving 3,062.2 linear feet of tunnel	0.00	456,784.26
Contract No. 10, Construction and maintenance of Transmission Line	8,332.27	110,917.23
Contract No. 12, Sinking Shafts 2, 3 and 4 and driving 3,809.6 linear feet of tunnel	0.00	632,727.44
Contract No. 14, Construction of East Portion of Wachusett-Coldbrook Tunnel and Shaft 1	1,384,006.55	3,033,167.26
Contract No. 17, Construction of West Portion of Wachusett-Coldbrook Tunnel and Shaft 8	1,541,417.20	3,933,654.67
Contract No. 18, Furnishing Iron Castings for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	6,391.22	19,431.07
Contract No. 19, Construction of Dam, and Substructure of Intake Building for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	132,017.22	227,411.29
Contract No. 24, Construction of Superstructure of Intake Building for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	7,555.60	7,555.60

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
PERMANENT CONSTRUCTION — *Concluded.*		
Contract No. 25, Construction of Superstructure of Outlet Building for the Wachusett-Coldbrook Tunnel	14,009.02	14,009.02
Total Contracts	$3,093,729.08	$8,726,239.83
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$37,956.77	$47,858.61
Temporary Equipment	— 19.50	5,013.60
Miscellaneous Expense	5,376.53	7,252.54
Contracts for Investigations and Surveys	0.00	898.34
Total	$43,313.80	$61,023.09
Total Wachusett-Coldbrook Tunnel Division	$3,429,656.97	$10,075,574.38

COLDBROOK-SWIFT TUNNEL DIVISION

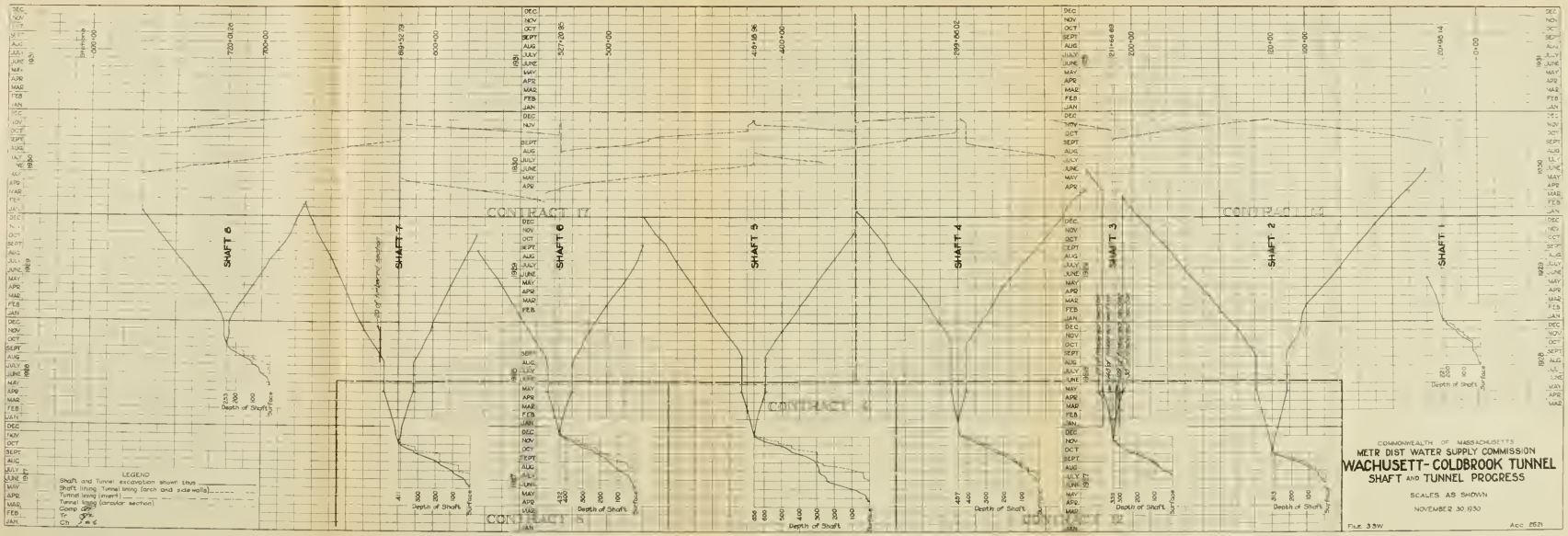
GENERAL OVERHEAD:		
Administration	$1,921.93	$7,353.50
Engineering	6,327.03	32,924.71
Total General Overhead	$8,248.96	$40,278.21
ENGINEERING:		
Salaries, Engineering and Clerical	$3,396.10	$36,241.25
Furniture and Fixtures	123.96	549.91
Engineering Instruments	118.55	3,473.80
Rent and Upkeep	968.34	3,858.44
Automobile Purchase	251.00	4,562.75
Automobile Maintenance	2,315.85	7,794.89
Contracts for Investigations and Surveys	0.00	12,831.65
Materials of Construction	0.00	2.25
Miscellaneous Expense (undistributed)	504.00	3,003.22
Printing and Blueprinting	61.26	270.07
Stationery and Office Supplies	205.34	1,043.81
Postage	43.18	182.30
Total Engineering	$7,987.58	$73,814.34
REAL ESTATE:		
Legal and Expert Expense	$214.31	$1,785.64
Miscellaneous Expense (undistributed)	7.40	19.70
Printing and Blueprinting	13.14	13.81
Purchases and Settlements	1,850.00	1,850.00
Taxes	22.50	22.50
Fire Protection Equipment	16.97	34.03
Total Real Estate	$2,124.32	$3,725.68
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$91.87
Total	$0.00	$91.87
Total Coldbrook-Swift Tunnel Division	$18,360.86	$117,910.10

Swift River Reservoir Division

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
General Overhead:		
Administration	$11,760.54	$48,713.27
Engineering	108,014.49	285,680.77
Total General Overhead	$119,775.03	$334,394.04
Engineering:		
Salaries, Engineering and Clerical	$44,132.70	$236,361.54
Labor	1,307.00	2,178.94
Furniture and Fixtures	207.87	2,696.04
Laboratory Equipment	258.34	258.34
Rental of Equipment	0.00	0.50
Engineering Instruments	0.50	5,436.39
Rent and Upkeep	599.38	2,264.28
Automobile Purchase	2,100.74	10,569.45
Automobile Maintenance	1,374.26	8,990.79
Special Experiments	272.52	392.40
Contracts for Investigations and Surveys	9,397.42	44,846.33
Office Buildings	820.30	4,835.91
Miscellaneous Expense (undistributed)	613.30	3,102.99
Printing and Blueprinting	101.44	859.10
Stationery and Office Supplies	330.42	3,078.94
Postage	56.40	321.50
Total Engineering	$61,572.59	$326,193.44
Real Estate:		
Legal and Expert Expense	$16,083.83	$93,775.83
Labor	11.25	67.35
Furniture and Fixtures	0.00	15.68
Miscellaneous Expense (undistributed)	939.87	2,342.31
Advertising	96.40	208.66
Printing and Blueprinting	307.85	357.65
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	777,759.23	4,019,696.69
Taxes	22,097.59	56,625.79
Maintenance of Real Estate	76.60	606.42
Fire Protection Equipment	220.20	2,724.44
Automobile Purchase	0.00	200.00
Automobile Maintenance	61.74	152.09
Miscellaneous Expense	9.91	65.52
Police Protection Labor	5.00	5.00
Special Agents, Salaries	2,370.00	6,111.33
Equipment	0.00	118.33
Automobile Purchase	308.00	917.96
Automobile Maintenance	416.41	1,250.14
Miscellaneous Expense (undistributed)	149.51	484.64
Printing and Blueprinting	0.00	41.60
Stationery and Office Supplies	0.00	3.52
Postage	2.00	4.42
Renting Agents, Salaries	2,600.00	7,255.43
Furniture and Fixtures	0.00	29.29
Stationery and Office Supplies	4.00	4.00
Miscellaneous Expense	101.49	207.96
Payments to Towns	2,000.00	4,000.00
Total Real Estate	$825,620.88	$4,197,272.50

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
SWIFT RESERVOIR DAMAGES:		
Salaries, Engineering	$00.00	$14.58
Consultant Expense	521.90	1,443.37
Purchases and Settlements	8,061.00	14,107.00
Miscellaneous Expense	.80	2.70
Total Swift Reservoir Damages	$8,583.70	$15,567.65
SWIFT DIVERSION DAMAGES:		
Salaries, Engineering	$5,098.48	$14,395.20
Consultant Expense	2,963.27	5,048.96
Engineering Instruments	25.65	555.35
Laboratory Equipment	154.45	174.44
Automobile Maintenance	0.00	1.25
Contracts for Investigations and Surveys	0.00	569.47
Laboratory Supplies	0.00	20.98
Miscellaneous Expense (undistributed)	109.04	2,890.92
Printing and Blueprinting	16.72	63.29
Rental of Equipment	9.00	9.00
Total Swift Diversion Damages	$8,376.61	$23,728.86
CEMETERIES:		
Salaries, Engineering and Clerical	$1,459.30	$2,776.81
Legal and Expert Expense	17.75	43.50
Labor	1,435.76	3,566.64
Miscellaneous Expense (undistributed)	15.09	80.89
Stationery and Office Supplies	0.00	3.51
Purchases and Settlements	1,675.50	3,552.00
Monuments and Inscriptions	8.00	244.55
Materials	641.97	1,525.56
Transportation of Bodies	0.00	45.00
Transportation of Monuments	396.00	778.00
Total Cemeteries	$5,649.37	$12,616.46
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$214.78
Total	$0.00	$214.78
Total Swift River Reservoir Division	$1,029,578.18	$4,909,987.73
SOUTHERN SUDBURY EMERGENCY SUPPLY		
GENERAL OVERHEAD:		
Administration	$13.04	$8,667.76
Engineering	93.76	33,397.03
Total General Overhead	$106.80	$42,064.79
ENGINEERING:		
Salaries	$0.00	$33,810.46
Consultant Expense	0.00	3,816.25
Furniture and Fixtures	0.00	30.70
Engineering Instruments	0.00	216.06
Rent and Upkeep	0.00	543.40
Automobile Purchase	— 200.00	1,719.00
Automobile Maintenance	0.00	1,514.45
Labor	0.00	173.00
Miscellaneous Expense (undistributed)	0.00	1,575.75

	Year ending Nov. 30, 1930	Total to Nov. 30, 1930
ENGINEERING — *Concluded.*		
Printing and Blueprinting	$0.00	$215.33
Stationery and Office Supplies	0.00	567.87
Postage	0.00	52.80
Total Engineering	$ — 200.00	$44,235.07
REAL ESTATE:		
Legal and Expert Expense	$360.57	$2,174.81
Consultant Expense	0.00	116.87
Printing and Blueprinting	3.31	3.31
Purchases and Settlements	11,150.00	27,638.22
Taxes	122.09	122.09
Total Real Estate	$11,635.97	$30,055.30
SOUTHERN SUDBURY DIVERSION DAMAGES:		
Consultant Expense	$120.50	$990.00
Legal and Expert Expense	0.00	212.66
Settlements	25,000.00	49,550.00
Total Southern Sudbury Diversion Damages	$25,120.50	$50,752.66
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 5, Cordaville Pipe Line	$0.00	$83,262.86
Contract No. 6, Cordaville Pumping Station	0.00	17,385.04
Contract No. 7, Hopkinton Pipe Line	0.00	134,365.72
Contract No. 11, Ashland Pipe Line	0.00	130,145.35
Contract No. 13, Whitehall Pipe Line	0.00	60,603.17
Contract No. 16, Whitehall Open Channel	0.00	32,695.16
Total Contracts	$0.00	$458,457.30
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$7,960.51
Miscellaneous Expense	0.00	2,758.77
Labor	0.00	1,011.00
Materials of Construction	0.00	207.09
Total	$0.00	$11,937.37
Total Southern Sudbury Emergency Supply	$36,663.27	$637,502.49
SUMMARY		
Wachusett-Coldbrook Tunnel Division	$3,429,656.97	$10,075,574.38
Coldbrook-Swift Tunnel Division	18,360.86	117,910.10
Swift River Reservoir Division	1,029,578.18	4,909,987.73
Southern Sudbury Emergency Supply	36,663.27	637,502.49
Unassigned	— 361.67	645.24
Grand Total	$4,513,897.61	$15,741,619.94
RECEIPTS FROM RENTS, SALES, ETC.		
Receipts from Sales	$20,316.76	$49,513.33
Receipts from Rents	45,716.19	103,681.52
Miscellaneous Receipts	416.52	526.90
Total Receipts	$66,449.47	$153,721.75



SHAFT 8
SHAFT 7
SHAFT 6
SHAFT 5
SHAFT 4
SHAFT 3
SHAFT 2
SHAFT 1
CONTRACT 17
CONTRACT 16
CONTRACT 6
CONTRACT 5
CONTRACT 12
Depth of Shaft
Surface
LEGEND
Shaft and Tunnel excavation shown thus
Shaft lining Tunnel lining (arch and side walls)
Tunnel lining (invert)
Tunnel lining (circular section)
Comp
Tr
Ch
COMMONWEALTH OF MASSACHUSETTS
METR DIST WATER SUPPLY COMMISSION
WACHUSETT-COLDBROOK TUNNEL
SHAFT AND TUNNEL PROGRESS
SCALES AS SHOWN
NOVEMBER 30, 1930
FILE 33W
Acc 2621

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

REAL ESTATE TAKINGS

TAKING FOR		TAKING NO.	TOWN	COUNTY	PLAN NO.	DATE OF TAKING	TITLE VESTED IN COMMONWEALTH FEE (Acres)	EASEMENT (Acres)
Wachusett-Coldbrook Tunnel.		1	Holden	Worcester	T-1 to T-5 incl.	July 22, 1927.	186.01	3.91
			Rutland				1.86	
Wachusett-Coldbrook Tunnel.		2	Rutland	Worcester	T-6 to T-12 incl.	Aug. 26, 1927.	90.90	8.92
			Oakham				6.62	2.00
Wachusett-Coldbrook Tunnel.		3	Oakham	Worcester	T-13	Nov. 11, 1927.	103.58	
			Barre				181.25	0.84
Wachusett-Coldbrook Tunnel.		4	West Boylston	Worcester	T-1A	Aug. 21, 1928.		2.57
			Holden					2.13
Coldbrook-Swift Tunnel.		1	Barre	Worcester	T-14	Sept. 24, 1929.		3.53
							570.22	23.90
Ashland Pipe Line.	Southern Sudbury Supply	1	Southborough	Worcester	C-1 & C-2	July 8, 1927.		0.85
			Ashland	Middlesex				4.48
Ashland Pipe Line.		2	Ashland	Middlesex	C-8 to C-11 incl.	Nov. 11, 1927.		9.13
			Framingham					1.34
Cordaville Pipe Line.		3	Southborough	Worcester	C-3 to C-7 incl.	July 8, 1927.	1.14	8.75
Hopkinton Pipe Line.		4	Hopkinton	Middlesex	C-12 to C-14 incl.	Oct. 14, 1927.	64.17	4.47
Cedar Swamp.		9	Hopkinton	Middlesex	C-15	Sept. 23, 1930.	193.50	
							258.81	29.02
Indian Brook	Emergency	5	Ashland & Hopkinton	Middlesex	No Plan	Sept. 2, 1927.	Water Diversion.	
Cold Spring Brook		6	Ashland	Middlesex	No Plan	Jan. 6, 1928.		
Sudbury River		7	Southborough, Hopkinton, & Westborough.	Wor. & Mid'sex. Worcester	No Plan	Jan. 6, 1928.		
City Brook & Whitehall Res.		8	Hopkinton	Middlesex	No Plan	Jan. 6, 1928.		

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED PRIOR TO NOV. 30, 1929

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
1	Borings	Tunnel Line	Ware & Swift	Pennsylvania Drilling Company	Nov. 5, 1926	Nov. 9, 1926	8,260.00	18,641.69	July 15, 1927
2	Borings	Swift Dam & Dike Sites	Swift	Sprague & Henwood, Incorporated	Nov. 5, 1926	Nov. 9, 1926	9,730.00	26,885.83	June 3, 1927
3	Aerial Photographs	Swift River Valley	Swift	Fairchild Aerial Surveys, Incorporated		Nov. 12, 1926	6,955.00	5,997.50	Nov. 2, 1927
4	Shaft 5	Rutland	Ware	James J. Coughlan & Sons, Incorporated	Mar 25, 1927	Mar. 28, 1927	137,854.80	290,581.99*	June 12, 1928
5	Cordaville Pipe Line	Cordaville to Sudbury Res.	So. Sudbury	Lock Joint Pipe Co.	Apr. 15, 1927	Apr 15, 1927	78,818.00	83,762.86	Jan. 9, 1928
6	Cordaville Pumping Station	Cordaville	So. Sudbury	F.A. Mazzur Co., Inc.	Apr. 29, 1927	May 2, 1927	16,357.00	17,385.04	May 16, 1928
7	Hopkinton Pipe Line	Hopkinton Res. to Cordaville.	So. Sudbury	Cenedella & Co.	Apr. 29, 1927	May 4, 1927	126,550.00	134,365.72	Dec. 27, 1927
8	Shafts 6 & 7	Rutland	Ware	James J. Coughlan & Sons, Incorporated	May 20, 1927	May 24, 1927	162,125.00	456,784.26*	June 12, 1928
9	Aerial Photographs	Chicopee and Ware Rivers	Ware	Fairchild Aerial Surveys, Incorporated		Mar. 30, 1927	3,090.00	2,560.00	Feb. 17, 1928
11	Ashland Pipe Line	Ashland Res. to Res. No. 2, Gate Ho.	So. Sudbury	Antonio Mogavero	June 3, 1927	June 3, 1927	125,150.00	130,145.35	Sept. 24, 1928
12	Shafts 2, 3 & 4	Holden & Rutland	Ware	Dravo Contracting Company	May 20, 1927	May 24, 1927	259,800.00	632,727.44*	June 12, 1928
13	Whitehall Pipe Line	Whitehall Res. to City Road	So. Sudbury	Portland Contracting Company, Incorporated	July 15, 1927	July 15, 1927	54,963.00	60,603.17	June 12, 1928
15	Electric Power	Cordaville Pumping Station	So. Sudbury	Marlborough Electric Company		Aug. 4, 1927		** 270.09	June 1, 1928
16	Whitehall Open Channel.	City Road to Hopkinton Res.	So. Sudbury	Sanders Engineering Company	Sept. 23, 1927	Sept. 23, 1927	36,720.00	32,695.16	July 9, 1928

*This amount includes construction beyond that which was contemplated when proposal was made.
**The Metropolitan District Commission has paid all bills for this contract subsequent to June 1, 1928.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS IN FORCE BETWEEN NOV. 30, 1929 & NOV. 30, 1930

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	BASIS OF AWARD	PAYMENTS TO DATE
10.	Transmission Line for Construction of Wachusett-Coldbrook Tunnel	Tunnel Line	Ware	New England Power Company		April 27, 1927	Maintenance at Cost Construction at Cost **	25,770.25 * 86,439.58
14.	East Portion Wachusett-Coldbrook Tunnel	West Boylston, Holden and Rutland	Ware	West Construction Co. Assignee	Nov. 18, 1927	April 30, 1928	4,074,981.25	3,033,167.26
17.	West Portion Wachusett-Coldbrook Tunnel	Rutland, Oakham and Barre	Ware	West Construction Co. Assignee	Nov. 18, 1927	April 30, 1928	*** 4,799,362.50	3,933,654.67
18.	Iron Castings for Ware River Intake Works	Barre	Ware	Barbour Stockwell Co.	Jan. 4, 1929	Jan. 8, 1929	18,697.83	19,431.07
19.	Dam and Substructure of Intake Building	Barre	Ware	J. W. Bishop Co.	July 16, 1929	July 23, 1929	273,077.00	227,411.29
22.	Unwatering Pump at Shaft 1	West Boylston	Ware	F. A. Mazzur Co., Inc.	Nov. 5, 1929	Nov. 12, 1929	11,975.00	
23.	Making Borings	Belchertown, Ware, Enfield, Greenwich & Hardwick	Swift	Sprague & Henwood Inc.	Nov. 5, 1929	Nov. 5, 1929	10,950.00	9,397.42
24.	Superstructure of Ware River Intake Building	Barre	Ware	Munroe & Wescott Inc.	July 22, 1930	July 22, 1930	69,669.00	7,555.60
25.	Superstructure of Outlet Works at Shaft 1	West Boylston	Ware	Munroe & Wescott Inc.	July 22, 1930	July 22, 1930	61,363.00	14,009.02
26.	Wiring and Electrical Equipment Outlet Works Shaft 1	West Boylston	Ware	Anderson-Coffey Co. Inc.	Sept. 23, 1930	Sept. 23, 1930	8,850.00	
27.	Earth Fill along Ware River	Barre	Ware	Raymond A. Bergesson	Sept. 23, 1930	Sept. 23, 1930	4,050.00	1,305.00

* This is the final estimate figure for the "Construction at Cost," portion of Contract 10.

** Portion of work completed under Contract 12 before Contract 14 was executed reduces this amount by about 7%.

*** Portion of work completed under Contracts 4 & 8 before Contract 17 was executed reduces this amount by about 7%.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TOTAL VALUE OF WORK ACCOMPLISHED UNDER CONTRACTS IN PROGRESS DURING YEAR ENDING NOV. 30, 1930 — SHOWN MONTHLY

CONTRACT NUMBER		10	14	17	18	19	22	23	24	25	26	27
CONTRACTOR		New England Power Co.	West Const. Co. (Assignee)	West Const. Co. (Assignee)	Barbour Stockwell Co.	J. W. Bishop Co.	F. A. Mazzur Co. Inc.	Sprague & Henwood, Inc.	Monroe & Wescott Inc.	Monroe & Wescott Inc.	Anderson-Coffey Co, Inc.	Raymond A. Bergesson
BASIS OF AWARD		Operation & Maintenance	$4,074,981.25*	$4,799,362.52**	$18,697.83	$273,077.00	$11,975.00	$10,950.00	$69,669.00	$61,363.00	$8,850.00	$4,050.00
DECEMBER 1929	Total to first of previous month	20,434.50	1,973,457.94	2,754,581.63	15,656.34	125,155.21		436.58				
JANUARY 1930		21,217.68	2,101,629.10	2,846,583.63	19,431.07			1,048.13				
FEBRUARY		21,948.78	2,210,620.15	2,885,933.75				1,714.93				
MARCH		22,713.30	2,307,036.40	2,949,265.85				2,826.17				
APRIL		23,419.25	2,396,502.04	3,091,246.05				3,787.61				
MAY		24,081.70	2,467,608.09	3,252,331.91				4,522.15				
JUNE		24,803.71	2,526,483.18	3,462,617.52		126,774.86		5,447.34				
JULY		25,682.22	2,530,905.28	3,641,214.17		154,145.06		6,161.93				
AUGUST		26,487.30	2,591,060.03	3,820,214.67		180,541.36		7,726.93				
SEPTEMBER		27,197.39	2,742,210.52	3,984,485.71		208,913.61		8,587.23				
OCTOBER		27,923.19	2,961,637.47	4,015,186.66		238,285.81		9,559.46		8,625.16		
NOVEMBER		28,633.61	3,231,296.96	4,065,171.86		252,679.21		10,441.58	8,395.11	15,565.58		1,450.00

* *Portion of work completed under Contract 12 before Contract 14 was executed reduces this amount by about 7%*
** *Portion of work completed under Contracts 4 and 8 before Contract 17 was executed reduces this amount by about 7%*
___ *Indicates final estimate for payment*

CANVASS OF BIDS FOR CONTRACT 27, OPENED SEPTEMBER 23, 1930

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
CONTRACT 27
FILLING WITH EARTH, AREAS ALONG THE BANK OF THE WARE RIVER IN THE TOWN OF BARRE

				* ① RAYMOND A. BERGESSON, Sagamore, Mass.		② R. H. NEWELL CO., Uxbridge, Mass.		③ KELLEHER CORPORATION, Turners Falls, Mass.		④ ANTHONY ROSS & SON, 97 Bedford Tr., Lexington, Mass.		⑤ H. & J. P. GREEN CO. INC., 1 Mt. Hope Terrace, Worcester, Mass.	
ITEM	DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT
1	Earth filling	Cu. Yd.	13,000	.29	3,770.00	.32½	4,225.00	.40	5,200.00	.45	5,850.00	.48	6,240.00
2	Drainage ditches	Lin. Ft.	1,000	.10	100.00	.50	500.00	.15	150.00	.25	250.00	.60	600.00
3	Riprap	Cu. Yd.	60	3.00	180.00	2.50	150.00	2.00	120.00	5.00	300.00	4.00	240.00
					$4,050.00		$4,875.00		$5,470.00		$6,400.00		$7,080.00

				⑥ PETER SALVUCCI, 25 Pond St., Waltham, Mass.		⑦ CHAS. E. HORNE, Millbury, Mass.		⑧ PORTLAND CONTRACTING COMPANY INC., 102 Exchange St., Portland, Maine.		⑨ GUARANTY CONSTRUCTION CO. INC., Shirley, Mass.		⑩ J. W. BISHOP CO., 109 Foster St., Worcester, Mass.	
ITEM	DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT
1	Earth filling	Cu. Yd.	13,000	.45	5,850.00	.54	7,020.00	.49	6,370.00	.65	8,450.00	.75	9,750.00
2	Drainage ditches	Lin. Ft.	1,000	1.00	1,000.00	.25	250.00	.80	800.00	.40	400.00	.35	350.00
3	Riprap	Cu. Yd.	60	4.00	240.00	4.00	240.00	6.00	360.00	8.00	480.00	2.50	150.00
					$7,090.00		$7,510.00		$7,530.00		$9,330.00		$10,250.00

				⑪ M. I. O'CONNOR, 696 Bridge Road, Northampton, Mass.		⑫ JAMES J. COUGHLAN & SONS INC., 27 School St., Boston, Mass.		⑬ WARNER BROS. & GOODWIN INC., Sunderland, Mass.		⑭ HENRY N. WORTHINGTON, 59 Bigelow St., Quincy, Mass.			
ITEM	DESCRIPTION	UNIT	QUANTITY	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT	PRICE	AMOUNT		
1	Earth filling	Cu. Yd.	13,000	.75	9,750.00	.77	10,010.00	1.00	13,000.00	1.25	16,250.00		
2	Drainage ditches	Lin. Ft.	1,000	.80	800.00	.75	750.00	.50	500.00	1.00	1,000.00		
3	Riprap	Cu. Yd.	60	3.50	210.00	5.00	300.00	2.00	120.00	5.00	300.00		
					$10,760.00		$11,060.00		$13,620.00		$17,550.00		

* *Contract awarded and executed Sept. 23, 1930.*

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

CANVASS OF BIDS FOR CONTRACT 24

FOR THE CONSTRUCTION OF THE

WARE RIVER INTAKE BUILDING

OPENED JULY 22, 1930
CONTRACT AWARDED TO MUNROE & WESTCOTT, INC.,
EXECUTED JULY 23, 1930

1.	Munroe & Westcott, Inc.	North Attleboro, Mass.	$69,669.00
2.	Long Construction Co.	185 Devonshire St., Boston	70,778.00
3.	J. M. & C. J. Buckley Co.	183 Essex St., Boston, Mass.	73,347.00
4.	L. Rocheford & Son, Inc.	44 Front St., Worcester, Mass.	74,440.00
5.	Simpson Bros. Corp.	77 Summer St., Boston, Mass.	82,330.00
6.	J. W. Bishop Co.	109 Foster St., Worcester, Mass.	85,000.00
7.	Duncan Rusk Corp.	West Townsend, Mass.	89,922.00
8.	John Bowen Co.	129 Newbury St., Boston, Mass.	90,900.00
9.	George W. Harvey Co.	79 Milk St., Boston, Mass.	114,127.00
10.	L. Luchini & Son	Milford, Mass.	121,228.00

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

CANVASS OF BIDS FOR CONTRACT 25

FOR THE CONSTRUCTION OF THE

WACHUSETT OUTLET BUILDING

OPENED JULY 22, 1930
CONTRACT AWARDED TO MUNROE & WESTCOTT, INC.,
EXECUTED JULY 23, 1930

1.	Munroe & Westcott, Inc.	North Attleboro, Mass.	$61,363.00
2.	Long Construction Co.	185 Devonshire St., Boston, Mass.	61,898.00
3.	L. Rocheford & Son, Inc.	44 Front St., Worcester, Mass.	66,450.00
4.	J. M. & C.J. Buckley Co.	183 Essex St., Boston, Mass.	66,745.00
5.	Simpson Bros. Corp.	77 Summer St., Boston, Mass.	70,960.00
6.	J. W. Bishop Co.	109 Foster St., Worcester, Mass.	75,640.00
7.	Duncan Rusk Corp.	West Townsend, Mass.	77,228.00
8.	John Bowen Co.	129 Newbury St., Boston, Mass.	78,190.00
9.	George W. Harvey Co.	79 Milk St., Boston, Mass.	93,148.00
10.	L. Luchini & Son	Milford, Mass.	104,584.00

CANVASS OF BIDS FOR CONTRACT NO. 26, OPENED SEPT. 23, 1930.

COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

CONTRACT 26.

FURNISHING AND INSTALLING
POWER AND LIGHTING WIRING, AND ELECTRICAL EQUIPMENT
AT THE OUTLET WORKS AT SHAFT 1, OF THE
WACHUSETT - COLDBROOK TUNNEL
IN
THE TOWN OF WEST BOYLSTON.

No.	CONTRACTOR	AM'T. OF BID.
1.	Anderson-Coffey Co. Inc., * 80 Boylston St., Boston, Mass.	$8,850.00
2.	Connor Electric Corp'n., 12 Pearl St., Boston, Mass.	8,950.00
3.	Lord Electric Co. Inc., 301 Columbus Ave., Boston, Mass.	9,893.00
4.	Sward Bros., Inc., 17-19 Mystic St., Arlington, Mass.,	9,950.00
5.	Coghlin Inc., 280 Main St., Worcester, Mass.,	9,965.00
6.	H.M. Haley Electric Co., Inc., 165 Pearl St., Boston, Mass.,	10,245.00
7.	Carleton-Mace Engineering Corp., 252 Dover St., Boston, Mass.,	13,505.00
The following was an informal bid sent in a letter dated 9-23-30.		
	Hixon Electric Company, 22 Elkins St., Boston, Mass.	$10,900.00

*Contract awarded Sept. 23, 1930.
Contract executed Sept. 24, 1930.

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1931, its

SIXTH ANNUAL REPORT

I. Organization and Administration

Davis B. Keniston continued during the year as chairman of the Commission, and Charles M. Davenport as associate commissioner, the latter being reappointed by the Governor. Joseph H. Soliday continued as associate commissioner until July 29, when he was succeeded by Thomas D. Lavelle, of Boston. R. Nelson Molt continued as secretary.

The clerical force of the Commission's office at Boston remained the same throughout the year, and three special agents under the direction of the Commission, continued to care for property acquired by the Commission in the Swift River and Ware River areas. Real estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 123 employees during the year. The maximum number employed at any one time by contractors on the various construction projects during the year was 523 persons.

II. Engineering Department

Frank E. Winsor continued as chief engineer, Karl R. Kennison as designing engineer and Walton H. Sears as mechanical engineer.

The field divisions were continued in charge of three division engineers as follows: Wachusett-Coldbrook Tunnel Division, William W. Peabody; Coldbrook-Swift Tunnel Division, Richard R. Bradbury; Swift River Reservoir Division, N. LeRoy Hammond.

The Commission retained the services of J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, and the services of X. H. Goodnough, Inc., as consulting engineers. Charles T. Main of Boston was employed from time to time as consulting engineer on mill and water power damages, and Dr. Charles P. Berkey of Columbia University continued as consulting geologist. Other consultants were employed from time to time as needed.

III. Offices

The office of the Commission and of the Chief Engineer continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston, until January 1, 1931, when it was moved to the top floor of the newly completed Metropolitan District Commission Building at 20 Somerset Street, Boston. The three division offices for the Wachusett-Coldbrook Tunnel, the Coldbrook-Swift Tunnel and the Swift River Reservoir continued at Holden, Hardwick and Enfield respectively. The laboratories for water analysis and soil testing were continued at Enfield.

IV. Real Estate

The Commission, for reservoir purposes, has concluded the purchase of (or has under option), a total of 45,663 acres of land in the Swift River watershed, and for sanitary protection and construction purposes in the Ware River watershed, a total of 2,794 acres.

The Commission acquired by eminent domain 544.81 acres of land in fee in the towns of Barre, Hardwick and Greenwich for construction purposes of the Coldbrook-Swift Tunnel, and in the town of Belchertown, 72 acres of land were also so acquired for the location of the spillway channel at the proposed main dam of the Swift River Reservoir.

Part of the state highway designated as Route 109, leading from the town of Belchertown to Ware, through the Village of Enfield, was relocated by the Commission and a direct route across the valley of the Swift River and below the proposed reservoir site substituted, and for this purpose 53.82 acres of land

in fee were taken together with such easements as were necessary for this construction.

Also, 82 acres of land in fee were taken for cemetery purposes in the township of Ware at the junction of this relocated highway with the old Monson Turnpike leading from the Village of Enfield to Palmer.

The Commission continued through duly appointed agents, the direction of the town government of the town of Prescott as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

V. Water Rights

The Commission on March 6, 1931, ordered a taking of the flood waters of the Ware River in excess of 85 million gallons daily in accordance with the provisions of Chapter 375 of the Acts of 1926, and on March 20, 1931, water was first diverted down Shaft 8 through the Wachusett-Coldbrook Tunnel into Wachusett Reservoir.

The total diversion of water from the Ware River into the Wachusett Reservoir through the tunnel from March 20 to June 14, inclusive, was 12,813,900,000 gallons.

The Commission, acting under the provisions of Section 4 of Chapter 321 of the Acts of 1927, has negotiated settlement with the Industrial Buildings Corporation of Chicopee, Massachusetts, successor in interest to the Dwight Manufacturing Company, of all damages for the present and future diversions of the waters of the Ware and Swift rivers.

VI. Connecticut Litigation

The Bill in Equity filed by the State of Connecticut in the United States Supreme Court against the Commonwealth of Massachusetts objecting to and seeking to enjoin the diversions from the Ware and Swift rivers authorized by Massachusetts legislation has been finally heard and determined. Oral arguments on the exceptions filed by Connecticut to the Master's Report were heard by the Court on January 5, 1931. The Commonwealth was represented by the Honorable Joseph E. Warner, Attorney General, and the Honorable Bentley W. Warren, Special Counsel, together with Gerald J. Callahan, Esquire, and R. Ammi Cutter, Esquire, as Associate Counsel. The opinion of the Court was rendered on February 24, 1931 and the final decree in accordance with the decision of the Court was filed March 23, 1931. The decree dismissed Connecticut's bill of complaint "without prejudice to her right to maintain a suit against Massachusetts whenever it shall appear that substantial interests of Connecticut are being injured through a material increase of the amount of the waters of the Ware and Swift diverted by or under the authority of Massachusetts over and above the quantities authorized by the Acts of 1926 and 1927 as heretofore limited by the War Department."

VII. Ware River Supply

The construction of the Wachusett-Coldbrook Tunnel was completed by West Construction Co. under two contracts, numbered 14 and 17. The construction of the diversion dam and building foundations at the Ware River intake works was completed by J. W. Bishop Co. under contract number 19. Filling earth areas along the banks of the Ware River in the town of Barre above the intake works at Shaft 8 was completed by Raymond A. Bergesson under contract number 27. Work was continued by Munroe & Westcott, Inc., under two contracts, numbered 24 and 25, for the construction respectively, of the superstructure of the intake building for the Ware River intake works at Shaft 8, and of the superstructure of the outlet works at Shaft 1; and by Anderson-Coffey Company, Inc., under contract number 26 for electrical work in the latter building; and the work on these contracts was practically completed.

Two contracts, numbered 28 and 29 were awarded to Anthony Ross & Son of Lexington, Massachusetts, for grading the grounds, respectively, of the Ware River intake building in the town of Barre, and of the Wachusett outlet building in the town of West Boylston. Work has been in progress under these contracts.

A contract, numbered 31 was awarded to E. D. Ward Company of Worcester,

Massachusetts, for constructing the superstructure of the head house at Shaft 4 of the Wachusett-Coldbrook tunnel in the town of Rutland, and work has been in progress under this contract.

VIII. Swift River Supply

Real estate and topographic surveys were continued during the year. In consequence of requests from relatives of deceased persons, over 500 bodies have been removed from this reservoir area and interred in other places.

A contract, numbered 20 was awarded to Wenzel & Henoch Construction Company of Milwaukee, Wisconsin, for constructing the 10.4 miles of the Coldbrook-Swift Tunnel, remaining to be completed between the Ware River intake works at Coldbrook and the Swift River Valley, in the towns of Barre, Hardwick and Greenwich, and work is well under way under this contract.

A contract, numbered 21 was awarded to The Lane Construction Corporation of Meriden, Connecticut, for constructing a substitute highway in the towns of Ware and Belchertown, for a portion of state highway route No. 109, in a location south of the main dam of the proposed Swift River Reservoir, including a bridge over the Swift River, and work under this contract is approximately two-thirds completed.

A contract, numbered 30 was awarded to Northern States Contracting Company of St. Paul, Minnesota, for constructing the stream control works preliminary to the building of the main dam, and a large amount of work has been completed under this contract.

A contract, numbered 32 was awarded to The Dravo Contracting Company of Pittsburgh, Pennsylvania, for constructing exploratory caissons at the proposed sites of the main dam and dike of the Swift River Reservoir in the town of Enfield and in the town of Ware, to disclose the character of subsurface material and conditions for the determination of the type and design of those structures, and work has been in progress under this contract.

A contract. numbered 34 was awarded to The Lane Construction Corporation of Meriden, Connecticut, for the construction of an entrance and driveways into the location acquired for cemetery purposes in the town of Ware, and work has been in progress under this contract.

IX. Watershed Protection

The Commission has purchased some additional properties for protection of the water taken from the Ware River, and in conjunction with the Department of Public Health has continued its studies of possible sources of pollution and the best methods of its elimination. Temporary chlorinating plants were installed at two points in the upper watershed of the Ware River to disinfect the effluent from the temporary State Prison Camp and the Rutland State Sanatorium and private hospitals in the town of Rutland.

As required by Chapter 66 of the Resolves of the Legislature for the year 1931, investigation has been carried on by the Commission with the Department of Public Health as a Joint Board as to the best practicable method of disposing of the sewage and other wastes within the watershed of the Quinapoxet and Ware rivers to protect from pollution the water supplies of the city of Worcester and the Metropolitan Water District, and a report in accordance with the provisions of said resolves has been prepared to be filed in the manner and at the time prescribed.

X. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

XI. Other Reports

The report of the Chief Engineer is herewith presented.

Respectfully submitted,
DAVIS B. KENISTON, *Chairman.*
CHARLES M. DAVENPORT, *Associate Commissioner.*
THOMAS D. LAVELLE, *Associate Commissioner.*

20 Somerset Street, Boston, Massachusetts,
January 15, 1932.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1931.

ORGANIZATION

In numbers the engineering organization has not materially changed during the year.

Karl R. Kennison, Designing Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, preparation of contract specifications, contract and working drawings. He also continued as principal assistant to the Chief Engineer.

Charles L. Coburn and Stanley M. Dore, Assistant Designing Engineers, continued their general supervision of the detailed work of the office; and Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. They have assisted in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Swift River Reservoir Division.

X. Henry Goodnough, Inc., and J. Waldo Smith, continued as Consulting Engineers. Dr. Charles P. Berkey of Columbia University has advised on geological matters. Charles T. Main, consulting engineer of Boston, Arthur A. Shurcliff, consulting landscape architect of Boston, and other experts were employed from time to time as required.

The employees under the direction of the Chief Engineer at the end of the year and the preceding year were as follows:

	Nov 30, 1930	Nov. 30, 1931
Headquarters Office, Designing Division	29	33
Holden Office, Wachusett-Coldbrook Tunnel Division	52	23
Hardwick Office, Coldbrook-Swift Tunnel Division	22	28
Enfield Office, Swift River Reservoir Division	24	39
Total Engineering Force	127	123

The maximum force during the year was 126, during the nine weeks ending January 31. The minimum force was 119, during the two weeks ending May 9. The average force for the year was 123.

OFFICES

The office of the Chief Engineer and Designing Divison was continued in the Boston Five Cents Savings Bank Building at 24 School Street, Boston, until January 1, when it was moved to the Metropolitan District Commission Building at 20 Somerset Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Swift River Reservoir Division was continued in the property of the Commonwealth formerly known as the Frances W. Chandler house on Quabbin Road, and the laboratories for water analysis and for soil testing were continued in the property of the Commonwealth formerly known as the Barlow House, in Enfield.

HEADQUARTERS OFFICE

Summary of the Year's Work

Connecticut Case. — In connection with the bill in equity filed by the State of Connecticut in the United States Supreme Court against the Commonwealth of Massachusetts, seeking to enjoin the diversions from the Ware and Swift rivers, data were prepared for the use of the attorneys. Final oral arguments of counsel on Connecticut's exceptions to the report of the Special Master were heard by the Court January 5, 1931. The unanimous decision of the Court was announced on February 24, 1931, denying the injunction and upholding the right of Massachusetts to make the proposed diversions as provided by the

State Legislature, subject to requirements of the War Department in the interests of navigation.

Real Estate. — In the Swift River Reservoir area, 3,384 acres were offered for sale by their owners this year, making a total so offered to date of 63,036 acres. Reports and recommendations were submitted to the Commission with respect to purchasing the same.

PROGRESS OF REAL ESTATE NEGOTIATIONS FOR SWIFT RIVER RESERVOIR
OWNERS' OFFERS TO SELL TO COMMONWEALTH

	Number of Offers	Total Area (Acres)	Area Not Required (Acres)	Title Vested in Commonwealth (Acres)
Total for Year ending Nov. 30, 1931	114	3,384	803*	5,085*
Total to Nov. 30, 1930	1,540	59,652x	7,745x	39,527x
Total to Nov. 30, 1931	1,654	63,036	8,548	44,612

Options outstanding Nov. 30, 1931, include 1,051 acres.
Acreage is based partly upon surveys and partly upon information obtained from deeds. xCorrections of the acreage are made from time to time as information is available. See appended table.
*Includes some offered in previous years.

Reports and recommendations were submitted to the Commission with respect to the purchase of real estate for sanitary protection in the Ware River watershed above the intake works at Coldbrook.

PROGRESS OF REAL ESTATE PURCHASES FOR WARE RIVER WATERSHED PROTECTION

	Title Vested in Commonwealth (Acres)
Total for year ending Nov. 30, 1931	707
Total to Nov. 30, 1930	2,087
Total to Nov. 30, 1931	2,794

Real estate taking plans were prepared and filed during the year as follows: — Five plans covering 67 parcels of land in the towns of Belchertown and Ware required for the relocated Ware-Belchertown highway; one plan covering 4 parcels of land in the town of Belchertown required for the spillway channel from the proposed main dam; one plan covering 5 parcels of land in the town of Ware required for the new cemetery development; fourteen plans covering 74 parcels of land in the towns of Barre, Hardwick and Greenwich required for the Coldbrook-Swift tunnel; one plan covering 1 parcel of land in the town of Oakham owned by the town and occupied by the schoolhouse, required for sanitary protection of the Ware River watershed.

Contracts and Specifications. — Working drawings for Contracts 14, 20, 24, 25, 26, 28, 30, 31 and 32 were prepared and issued. The preparation of plans and specifications for extending the Wachusett-Coldbrook tunnel to the Swift River under Contract 20 by constructing the Coldbrook-Swift tunnel in the towns of Barre, Hardwick and Greenwich was continued and the contract was executed on April 23.

Plans and specifications were prepared for Contract 21 for constructing a portion of the Ware-Belchertown highway in the towns of Ware and Belchertown, in order to relocate this highway, Massachusetts Route No. 109, outside and south of the proposed Swift River Reservoir. The contract was executed July 20.

Plans and specifications were prepared for Contracts 28 and 29 for grading the grounds at the Ware River intake building in the town of Barre, and at the Wachusett outlet building in the town of West Boylston, respectively. These contracts were executed August 17.

Plans and specifications were prepared for Contract 30 for constructing the stream control works at the main dam of the Swift River Reservoir in the towns of Belchertown, Enfield and Ware. The contract was executed August 1.

Plans and specifications were prepared for Contract 31, for constructing the superstructure at Shaft 4 of the Wachusett-Coldbrook tunnel in the town of Rutland, this shaft being left open as a point of access into the Wachusett-Coldbrook tunnel. The contract was executed August 26.

Plans and specifications were prepared for Contract 32, for constructing exploratory caissons at the main dam and at the dike of the Swift River Reservoir in the towns of Enfield and Ware to accurately determine the material

overlying bed rock and to guide in the design of a watertight cutoff. The contract was executed September 16.

Contract 33 for the purchase of electricity at Shaft 1 and elsewhere on the Wachusett-Coldbrook tunnel was prepared. The contract was executed August 6.

Plans and specifications were prepared for Contract 34, for constructing driveways in a new cemetery to be established as required under the provisions of Section 9 of Chapter 321 of the Acts of 1927. The contract was executed October 29.

Inspection and Tests. — E. L. Conwell and Company of Philadelphia, Pa., continued the testing of cement. The Worcester Polytechnic Laboratory continued the testing of concrete cylinders and steel reinforcement bars. Charles T. Main, Inc., of Boston inspected electrical appliances and construction in connection with the work under Contracts 22, 24, 25 and 26. The inspection of the pump furnished under Contract 22, and of the two bridge cranes purchased by the Commission and installed in the buildings at Shafts 8 and 1 under Contracts 24 and 25, respectively, was made by the engineering force, which also continued the inspection of miscellaneous equipment and of structural steel work furnished under Contracts 24 and 25.

Acceptance tests of the tunnel unwatering pump at Shaft 1, furnished and erected by F. A. Mazzur Co., Inc., under Contract 22, were run between September 11 and October 17 under the supervision of the engineering force, and the pump was accepted. When the tunnel unwatering was complete the tunnel was inspected, all debris found in the tunnel was removed and a suitable screen of stainless steel was placed over the intake sump of the pump.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey. A concrete flume with submerged weir control, designed to provide a suitable, well defined measuring station, was constructed by day labor under the supervision of the engineering force at a point just downstream from the Ware River intake works.

The gaging station on the Chicopee River at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and also with the United States Geological Survey and further discharge measurements were made from time to time to define the rating curve more exactly.

During the year permission was granted by the Ludlow Manufacturing Associates to establish a gaging station on the Chicopee River at their Red Bridge hydro-electric plant. The necessary gages and other equipment were installed and the company is cooperating in the collection of data. The rating of the water wheels is in progress.

The gaging station on the Swift River at the plant of the Boston Duck Mills of the Otis Company at Bondsville was continued through the courtesy and with the cooperation of the owners.

Cooperation with the United States Geological Survey in the operation and maintenance of the gaging station on the Connecticut River at Thompsonville was continued.

In connection with the examination of the waters of the Ware, Swift and Chicopee rivers, observations of flow were continued from time to time and additional temporary gaging stations established as required.

Commencement of Ware River Diversion

The diversion of Ware River water into Wachusett Reservoir came at a most opportune time as this reservoir in February, 1931, was at the lowest point in its history, namely 45 feet below normal high water, the available storage having been reduced since June, 1929, from 55 billion gallons to 11 billion gallons. The addition to this storage of practically 13 billion gallons from the Ware River, equivalent to about three months' supply to the Metropolitan District, coupled with a spring flow from the Wachusett watershed itself in excess of normal, ended the immediate menace of a water shortage.

The intake works at Shaft 8 and the Wachusett-Coldbrook tunnel were completed sufficiently on March 1 to allow the diversion to be made. The superstructure of the intake building had not been erected but the heating plant had been installed in the basement and small temporary wooden housings had been

built over the operating panel, siphon break pipes, switchboard and other apparatus above the main floor of the building in order to commence operations and obtain the first water available.

The intake works have been described in previous reports, particularly in the fourth annual report, in which was published a plan of the diversion dam across the Ware River and the intake building with its siphon spillways through which the flood flows in excess of 85 million gallons daily from the river are diverted into a pit in the basement of the building directly over the shaft; also a cross section through the intake building and the shaft showing the regulating valves in the bottom of the pit discharging into the shaft, and the cast iron helical vanes from top to bottom of the shaft.

The diversion dam across the river just downstream from the tunnel shaft acts as a spillway to pass such occasional flood peaks as may exceed the capacity of the diversion works; or during the summer months from June 15 to October 15, to pass the entire flow of the river. From October 15 to June 15 or during the allowable period of diversion, the river flows normally over a weir in the foundations of the intake building, through a 52-inch Venturi meter, back into the river below the spillway. The entire specified 85 million gallons daily will flow past the dam in this manner without raising the pond level closer than 1 foot to the crest of the main spillway, this foot leeway being thus available in the operation of the diversion works.

The nine siphon spillways constructed in the foundation walls of the intake building between the river and the shaft, through which the diversion is accomplished, vary in capacity from 60 to 550 cubic feet per second under a 9-foot head. The crests of these siphons are 1 foot below the level of the main spillway, and siphon break pipes are set at this level so that whenever the pond is lower than this level, which corresponds to 85 million gallons daily flow in the river, the siphons are automatically broken and no water can be diverted into the tunnel. On a rising flood the rapid priming of the siphons in succession, one after the other up to the required capacity, is assisted by a series of float switches, specially designed for sensitiveness, which automatically connect each siphon in its turn to a vacuum pipe system in the building. The central pit over the shaft into which the nine siphons discharge is automatically kept filled with water at all times to seal the shaft against the entrance of air and to back the water up to the required head on the siphon spillways.

The works are designed with an ultimate capacity of about 2,000 million gallons per day. Such a flow, after the Swift River Reservoir is completed, will divide at the bottom of the shaft and flow part to the Swift River Reservoir and part to the Wachusett Reservoir. Under the extreme rate of diversion, the entire 9-foot head on all spillways will be required. Until the Swift River Reservoir is completed, the present capacity of the works, flowing only in an easterly direction toward the Wachusett Reservoir, is limited to a little over half this quantity. In ordinary operation only a small head is required on the siphons.

To maintain this required head by fluctuating the water level in the pit inside the building and also to prevent air from entering the tunnel, the top of the shaft is sealed with a floor or plug of reinforced concrete about 9 feet thick which is the floor of the pit on which four butterfly valves of the Dow-Disc type are installed. These valves are operated by oil pressure cylinders capable of taking 250 pounds per square inch oil pressure, but normally requiring only about 50 to 75 pounds. The valves are normally under a water head of about 40 feet and the top of the highest bell-mouth entrance is always submerged at least 18 feet and usually 25 feet. Only one of these valves, 6 feet in diameter, is ordinarily used since it can take care of all flows up to about 600 million gallons per day. A 120-inch Venturi meter to measure the flow is built into the bell-mouth entrance above this valve. The three other valves are each 5 feet in diameter and are opened one after the other as soon as the capacity of the first large valve is exceeded.

The discs of these valves are held by the oil pressure at just the right angle to pass the available flow in excess of 85 million gallons daily in the river and to hold the water in the pit at just the right level so that the siphon will pull this quantity from the river. Each butterfly valve responds under the oil pressure to the exact setting of a sleeve valve on the oil pressure and return lines, all the

sleeve valves being grouped together on a small operating panel in one corner of the main floor of the building. Except when under manual control, this setting is changed automatically, being connected to the cross head of the oil cylinder of the butterfly valve through a small steel cable running through the building over pulleys as required and through the water in the pit. Thus the only mechanical connection between the valves in the bottom of the pit and the operating panel is by the cable, the flexibility of which accommodates itself to the swirl of water in the pit.

The water is discharged through these valves and impinges tangentially at high velocity against the cast iron lining of the shaft. The helical vanes on this lining cause a rotation of the falling water which is pressed by centrifugal force into a thin film against the cast iron wall of the shaft. That the entrance of air into the tunnel is effectively prevented by the valve-controlled water cushion at the top of the shaft is shown by the high vacuum observed in the shaft.

The valve pit or basement of the diversion works was filled for the first time on March 20, and on March 21, water was diverted into the tunnel and the works were operated whenever the flow in the Ware River exceeded 85 million gallons a day, except in the period from June 15 to October 15, inclusive, when in conformity with the requirements of the War Department no water was diverted. Water was diverted on the following days: March 21 to May 5, May 9 to May 20, May 22 to June 4 and June 9 to June 14, inclusive. The flow in the river was not sufficient on any day from October 15 to the end of the year, November 30, to permit diversion. The following quantities of water were diverted weekly:

	Gallons
Sat. Mar. 21	8,000,000
Mar. 22–28	777,700,000
Mar. 29–Apr. 4	3,685,700,000
Apr. 5–11	2,925,900,000
Apr. 12–18	1,330,000,000
Apr. 19–25	215,100,000
Apr. 26–May 2	452,900,000
May 3–9	142,500,000
May 10–16	794,500,000
May 17–23	198,100,000
May 24–30	531,300,000
May 31–June 6	137,000,000
June 7–13	1,495,800,000
Sun. June 14	119,400,000
Total	12,813,900,000

The maximum rate of diversion occurred on Saturday, April 4, when water was dropped into the tunnel at an average rate for the 24 hours of 627 million gallons per day or about 30 tons per second. At moderate rates up to 250 million gallons per day, the water drops the entire distance, down the spirally lined shaft, to the crown of the tunnel. As the rate increases to about 300 million gallons per day, the water level in the tunnel rises and seals the bottom of the shaft.

Observations during the diversion at a gauge provided for the purpose indicate that a vacuum equivalent to about 25 feet of water is created and maintained in the shaft at all diversions in excess of about 300 million gallons per day. This vacuum causes the water level to rise in the shaft so that, for example, water diverted at the rate of 627 million gallons per day, the maximum last spring, after passing through the regulating valves and the plug in the top of the shaft and whirling around the shaft through a height of approximately 100 feet of rarefied air, strikes a water cushion approximately 100 feet deep in the lower half of the shaft. On the other hand, smaller rates of flow of say 250 million gallons per day after passing through the regulating valves, whirl through a height of about 200 feet into a water cushion about 15 feet deep.

During the first month the works were operated largely by manual control in three shifts, at least one operator being on hand at all times to make adjustments. Commencing April 19, the works were successfully placed in automatic operation with an operator on hand only during the ordinary working hours of the day. Diversion of the allotted flood flows continued without attendance nights, Sundays and holidays, entirely automatically except when manual control was cut in on several occasions during the daytime for special purposes.

During August several inspections were made of the shaft, the tunnel near the bottom of the shaft and the steel bulkhead about 2,250 feet west of the shaft. On September 15, the tunnel was inspected between Shaft 8 and Shaft 4, a distance of 8.0 miles and on September 18, coincident with the completion of the unwatering of the tunnel at Shaft 1 during the acceptance test of the tunnel unwatering pump, the tunnel was inspected from Shaft 4 to Shaft 1, a distance of 5.3 miles. The tunnel was found to be in excellent condition there being no evidences of damage to the lining at any point.

Design of Structures

Shaft 1. Wachusett Outlet Works. — Studies were made of the grading of the grounds about the shaft outlet building including the area south of Holden Street which had been used during the period of tunnel construction for a spoil bank area and for a settling basin for the collection and chlorination of tunnel pumpage before discharge into the Wachusett Reservoir. Final designs included the levelling of the settling basin dikes and the covering of the tunnel spoil bank and other areas with soil so as to remove all scars upon the landscape caused by the construction operations. These designs also included a driveway of bituminous macadam including a 100-foot diameter circle in front of the building and a low wall of field stone capped with granite slabs extending for a distance of 340 feet along Holden Street in front of the building. Plans included landscape treatment with trees and shrubbery.

Shaft 4. Superstructure. — The head house over Shaft 4 was designed to present an attractive appearance and require a minimum of maintenance. The exterior walls are of granite from quarries in Uxbridge, Massachusetts. The inside wall surface is of face brick. The structural steel framework of the roof serves to support the tackle used for hoisting into and out of the shaft.

Shaft Hoist. — For hoisting men and equipment at all shafts except Shafts 1, 5 and 8, and for cemetery removal work, an automobile truck was purchased on which was installed a hoist operated by the automobile engine. Five hundred fifty feet of non-spin cable was purchased for use at the tunnel shafts, also a shorter length for use in handling monuments and headstones in the Swift River valley. The truck is also equipped with an A-frame for emergency use at any shaft where there is no head house as well as for current use in the cemetery removal work. This apparatus was used at Shaft 4 during the inspection of the Wachusett-Coldbrook tunnel before the superstructure at Shaft 4 was erected.

Shaft 8. Ware River Intake Works. — Studies were made of the grading of the grounds about the intake works. Final designs included the filling of the trash and ice sluiceway discharging from the old White Brothers mill canal into the river about 400 feet downstream from the intake works, making provision for stop planks across the old canal to hold a constant water level therein during the period of water diversion, the re-grading of spoil banks to preserve existing trees and the covering with soil of all spoil banks on the north bank of the river downstream from the intake works and extending also a considerable distance upstream. These designs also included a driveway of bituminous macadam including an 80-foot diameter circle in front of the building and a low wall of field stones capped with granite slabs extending for a distance of about 550 feet along the state highway. Plans included landscape treatment with trees and shrubbery.

Shaft 12. Swift River Intake. — Designs were completed for the low level intake from Quabbin Lake. The intake provides a weir 36 feet long at elevation 427 above mean sea level over which the first diversion of water into the tunnel can be made. It also provides for the placing of permanent stop logs on this crest to elevation 439 and for a permanent low level intake between elevation 439 and 454.3. The design also provides means for removal of the stop logs at any future time if it should be found necessary to draw the Swift River Reservoir down to extremely low levels.

Studies were made of the high level intake and of designs for the substructure of the Swift River intake works. These works will allow flow in either direction from or into the Swift River Reservoir, the maximum capacity of the tunnel to discharge floods from the Ware River westerly into the Swift River Reservoir being about 80% greater than the maximum capacity of delivery easterly from

the Swift River Reservoir to the Wachusett Reservoir. On account of the diversions, from both the Ware and Swift rivers, into the Wachusett Reservoir, the gates controlling the flow into the Wachusett Reservoir are to be placed at the Wachusett end of the tunnel; hence, the Swift River intake works must act at times as a spillway to discharge all the water that can be diverted into the tunnel at the Ware River. On that account the Swift River intake works are designed without gates to allow free flow to and from the tunnel at all times except when cut off by the use of stop shutters. The design includes a double row of stop shutters the entire depth of the shaft.

Main Dam, River Diversion. — Studies were continued of the location of the main dam and dike for the proposed Swift River Reservoir. The location of the main dam was fixed approximately to the extent required in the design of cofferdams to be partially constructed with spoil obtained from excavations for the river diversion tunnel and approaches. The location of the diversion tunnel was fixed extending for a distance of about 960 feet through sound bed rock in the hill which forms the west abutment of the dam. The dimensions of the tunnel are 30 feet wide by 28 feet high, the section being of horseshoe shape. About 260 feet of cut and cover section extending from the upstream portal of the tunnel makes the entire length between the intake and outlet about 1,220 feet. An upstream approach channel about 550 feet in length and a downstream discharge channel about 1,300 feet in length connect with the river. The bottom of the upstream channel is to be lined with concrete for a depth of 6 feet to reduce seepage of water into the excavation for the dam foundations.

In order to locate the tunnel in sound ledge for as great a length as possible and to permit economical location of the tunnel portals, the tunnel will be straight, from the intake throughout the greater part of its length; it is then gradually enlarged in cross section, by gradual deepening or lowering of the invert keeping the same arch dimensions, and then just before the tunnel emerges at the downstream portal it is turned through an angle of approximately 90°, the increased cross section being maintained throughout the bend. As a result, there are no bends in the main portion of the tunnel where the velocity will be high but only after the velocity has been decreased by gradual enlargement near the downstream end.

A shaft in sound bed rock directly over the diversion conduit will provide a high level intake from the reservoir, the entrance to the diversion tunnel itself acting as a low level intake. To allow for the ultimate plugging of the diversion conduit at the completion of the main dam construction, two piers will be constructed directly beneath the shaft, splitting the conduit at this point into three 9-foot bays for the insertion of stop shutters to allow the construction of a solid plug of concrete, 40 feet long and filling the entire section of the tunnel. That portion of the diversion tunnel upstream from the piers is increased in height to 32 feet and the cross-sectional area of the conduit gradually reduced through the section at the piers so that when the conduit is discharging at full capacity the velocity of flow continually increases as it passes the piers, thus minimizing the loss of head.

To carry the flow of the river during the operation of plugging the conduit, provision is made for a large siphon pipe easily accessible from the shaft, in which a vacuum can be created to lift the water over and around the plug discharging into the tunnel downstream from the plug. To make provision for the required releases of water after the conduit is plugged, a 48-inch pipe will be embedded in the tunnel invert for the entire distance from the diversion conduit plug to a point in the channel, well below the outlet of the diversion tunnel. Studies were made of structures which will later be required to measure and control the release of water from the reservoir at the main dam.

Main Dam and Dike. — Studies were made of designs for the main dam and dike and methods of construction of the same. Designs were made for experimental caissons of concrete 12 feet thick by 32 feet long to be sunk by open dredging as far as possible and then by the use of compressed air and to be sealed to the ledge. A location was selected for one caisson at each site. The caisson at the main dam starts from the bottom of a small open cut about 17 feet above the elevation of the river, and at a considerable distance from the river and railroad, and will be sunk to a depth of about 70 feet below the river.

The caisson at the dike will start practically from the original surface in the bottom of the valley near the brook and only a few feet higher than the brook and will be sunk a total depth of about 120 feet.

Photographic Records. — Moving pictures were taken from time to time to illustrate the progress of construction work and to record existing conditions in the Swift River valley.

Water Supply Yield. — Studies were continued of the safe yield of the combined sources of water supply, both existing and proposed, particularly with reference to the capacity of the Swift River Reservoir in order to determine the best elevation of the flow line of the reservoir.

Protection of Water Supply. — Studies were continued of the removal of sewage from parts of Rutland and Holden and the watersheds of the Ware and Quinapoxet rivers, acting in conjunction with the Engineering Division of the Department of Public Health. Under the provisions of Chapter 66 of the Resolves of 1931 estimates were made of the costs of different methods of removing this sewage.

Cemetery Development. — Studies were made of the new cemetery development on land acquired for this purpose by the Commission. The layout of driveways and landscaping was planned in an area of approximately 6 acres selected for the first development and arrangement of lots was tentatively determined.

Highway and Railroad Relocation. — Preliminary studies were continued of highway and railroad relocations which may be required because of the construction of the Swift River Reservoir. Preparation of plans for Contract 21 for the relocation of a portion of the Ware-Belchertown highway, included the design of a 3-span reinforced concrete bridge across the Swift River. Plans of the relocated highway and designs for drainage were prepared in the Enfield office as hereinafter described.

Wachusett–Coldbrook Tunnel Division — Holden Office

The Wachusett-Coldbrook Tunnel Division continued in charge of the construction of the Wachusett-Coldbrook tunnel, with the exception of Shaft 8, and also of the tunnel outlet works at Shaft 1. Commencing October 1, the division took charge of all construction work in the vicinity of the Ware River intake works at Shaft 8, and of the maintenance and operation of the intake works.

Office Work

Tunnel sections were plotted and excavation and masonry volumes computed therefrom. Semi-monthly estimates were prepared for Contracts 14 and 17, monthly estimates for Contracts 10, 22, 25, 26, 28, 29 and 31, and final estimates for Contracts 10, 14 and 17. Additional geological field notes and specimens were prepared for a permanent geological record. Studies were continued of the character of materials available for concrete aggregates from the tunnel excavation at Shaft 2. Plans were prepared covering about 1,200 acres of topography along the lines of proposed trunk sewers in connection with investigations of the diversion from the Ware and Quinapoxet watersheds of sewage and sewage effluents in the towns of Rutland and Holden. Real estate plans were prepared covering about 350 acres in the Ware River watershed.

Field Work

Lines and grades were given for construction work on Contracts 14, 17, 22, 25, 26, 28, 29 and 31. Photographs of the construction work and of rock formations of geological interest were continued. Preliminary topographic surveys were made of an area extending from the Holden-Worcester line, through the towns of Holden, Rutland, Oakham and Barre, in connection with studies of various methods of the disposal of sewage and other wastes within the watersheds of the Quinapoxet River, and the Ware River above Coldbrook. Topographic surveys were made of the tunnel spoil banks at Shafts 1 and 2. Real estate surveys covering about 500 acres were made in the Ware River watershed. Stone property bounds were set from time to time to mark land purchased by the Commission.

Samples of concrete for testing were taken, and records were continued of the amount of cement used at all points of the work, particularly in lining the Wachusett-Coldbrook tunnel, the total amount used during the year being in

excess of 16,000 barrels. The inspectors employed to test the cement at the mills before shipment were kept advised in advance of all requirements.

The State Department of Public Health continued its cooperation with this division in the analysis of samples of drinking water and of sewage effluents. Two chlorinator stations were established on the Ware River Watershed, one to chlorinate the sewage effluent from the treatment plant of the temporary Rutland Prison Camp and Hospital and the other on Mill Brook below the Rutland State Sanatorium and the Central New England Sanatorium. These stations were operated from January 20 to June 19, inclusive.

Tile markers were placed in the concrete side walls of the Wachusett-Coldbrook tunnel at intervals of 500 feet along the tunnel and at the bottom of each shaft. Bench marks also were placed in the tunnel at the bottom of each shaft and in the outlet building of the Wachusett-Coldbrook tunnel.

The division office cooperated with the Headquarter's Office in the unwatering of the Wachusett-Coldbrook tunnel and in the inspection of the mechanical equipment for unwatering.

Construction by Force Account

The Mill Brook chlorinator plant referred to above was constructed by force account with labor employed and supervised by the division office. The labor used in the construction of the Rutland Prison Camp chlorinator was furnished from the camp by the State Department of Correction and supervised by the division office. The buildings for these stations were taken from property of the Commonwealth purchased from the West Rutland Worsted Company and moved to prepared foundations. Each station was heated electrically by thermostat control. Manually controlled vacuum feed chlorinators were used.

A submerged weir control was built across the Ware River below the Coldbrook gaging station by force account with labor employed and supervised by the division office. This weir was rated by current meter measurements.

Progress of Contracts

Contract 10.—Contract 10 with the New England Power Company, for constructing, maintaining and operating a 22,000-volt transmisison line along the Wachusett-Coldbrook tunnel line was practically terminated March 21 when the power was shut off. The cost of operation and maintenance included in estimates during the year, and covering the period from October 1930 to June 10, the date of the final estimate, was $4,474.20. Electric power continued to be purchased from this company by the contractors under Contracts 14 and 17. The total power furnished during the year was 2,324,800 K.W.H. including line and transformer losses. This total after line losses (but including transformer losses) was distributed to the different shafts as follows:

	K.W.H.
Shaft 1	135,998
Shaft 2	596,855
Shaft 3	0
Shaft 4	616,469
Shaft 5	231,300
Shaft 6	7,224
Shaft 7	393,564
Shaft 8	323,675
Total	2,305,085

The total electrical power consumed on Contracts 14 and 17 from April 30, 1928 to March 21, 1931 (not including the earlier shaft contracts) was approximately 36,200,000 K.W.H. The total length of tunnel excavated under these contracts was 66,662 linear feet and the total length lined 74,870 linear feet.

Wachusett-Coldbrook Tunnel.—Work on the tunnel was continued to completion under Contracts 14 and 17 by the West Construction Co., who continued to lease from the Commission various buildings at West Rutland as general headquarters until about August 16, and to employ until the completion of the work local physicians who made weekly reports on the health of the contractors' employees and on the sanitary condition at each of the contractors' camps.

Contract 14.—Contract 14 is for the construction of the east portion of the Wachusett-Coldbrook tunnel through West Boylston, Holden and Rutland, and extends from Shaft 1 at the upper end of the Wachusett Reservoir near Oak-

dale to a point 5,814 feet west of Shaft 4 and 5,819 feet east of Shaft 5. Work on this contract was continued, and practically completed on April 15, except for the removal of plant and camp buildings at Shafts 2 and 4 and general cleaning up. The contractor was permitted with certain restrictions to store portions of his equipment on areas adjacent to Shafts 2 and 4 and deposited with the Commission a sum to guarantee removal of such equipment.

Two complete tunnel concrete plants were continued in use for placing the side walls and arch and were moved along the entire length of the Wachusett-Coldbrook tunnel irrespective of contract limits as is hereinafter described.

The value of work included in contract estimates during the year was $284,490.12, the final estimate, dated July 28, being for $3,515,787.08, $10,000.02 being still retained at the end of the year.

Shaft 1. — At the beginning of the year practically all work at Shaft 1 had been completed except a small amount of grading, placing of gratings and covers in the top of the shaft and miscellaneous work. On March 8 all the contractor's pumping equipment which had been installed at the bottom of the permanent pump well was removed. All work was practically completed about April 30.

Shaft 2. — Tunnel lining operations at Shaft 2 were continued to completion on February 8 when dismantling of plant equipment was started. On March 7 the shaft and tunnel had been cleaned and the top of the shaft covered with temporary planking. On March 28 the concrete shaft top was poured. This top includes ventilator openings and hinged covers for access to the shaft as well as for emergency spillway discharge of water, the entire top being enclosed in a high iron fence. The camp buildings were dismantled early in July. The contractor's force averaged 44 men up to July 25. The average number of persons occupying the camp until it was closed on March 6 was 37, the maximum population being 68 during the week ending December 5, 1930.

Shaft 3. — As stated in previous reports, no major operations were carried on at this shaft. On January 5 the shaft top of pre-cast beams and slabs was placed. Filling and grading over and about the shaft top was completed on January 24.

Shaft 4. — Tunnel lining operations at Shaft 4 were continued until early in February. On February 21 dismantling of plant equipment was started. On April 14 the concrete shaft top comprising the foundations for the shaft head house was placed. The camp buildings were dismantled during July and August. The contractor's force averaged 41 men up to July 25. The average number of persons occupying the camp until it was closed on March 6, was 30, the maximum population being 45 during the week ending December 13, 1930.

The total work done and materials furnished under the principal items of Contract 14 are as follows:

Earth excavation for shafts	1,677	cu. yds.
Rock excavation in shafts and in tunnel within 50 ft. of shafts	3,237	" "
Excavation in tunnel, except within 50 ft. of shafts	205,099	" "
Shaft and tunnel drainage	33,601	lin. ft.
Forms for preliminary concrete linlng, Shaft 1	218	" "
Forms for concrete lining in tunnel	33,702	" "
Concrete masonry in shafts	2,880	cu. yds.
Concrete masonry in tunnel	73,356	" "
Concrete masonry not in shafts and tunnel	2,445	" "
Permanent timbering in tunnel	3.09	M ft. B. M.
Temporary timbering in tunnel	4.25	M ft. B. M.
Portland cement	118,630	bbls.
Earth excavation except for shafts	19,495	cu. yds.
Rock excavation except in shafts or tunnel	1,639	" "
Refilling and embankment	22,276	" "
Miscellaneous cast iron, wrought iron and steel	422,532	lbs.

Contract 17. — Contract 17 is for the construction of the west portion of the Wachusett-Coldbrook tunnel through Rutland, Oakham and Barre, and extends westerly from the work covered by Contract 14. The westerly limit of the excavation is 4,998 feet and that of the lining 4,967 feet west of Shaft 8. Work on this contract was continued, and practically completed on April 15, except general cleaning up. The contractor was permitted under an agreement similar to that made for Contract 14 to temporarily store his equipment on areas adjacent to Shafts 5, 6 and 7 and across the highway from Shaft 8.

The value of work included in contract estimates during the year was $61,922.33, the final estimate, dated May 15, being for $4,127,094.19.

Shaft 5. — Tunnel lining operations at Shaft 5 were continued until December 13. On January 5 dismantling of plant equipment was started. On February 21 the shaft and tunnel had been cleaned. On April 4 the shaft top of pre-cast beams and slabs was placed. Filling and grading over and about the shaft top was completed on April 8. The contractor's force averaged 7 men up to April 11. The contractor's camp at this shaft was not occupied during the year.

Shaft 6. — At the beginning of the year all concreting operations at this shaft had been completed and most of the contractor's camp and equipment removed. On December 18 the shaft top of pre-cast beams and slabs was poured. Minor details of the top were not completed until early in April when the filling and grading over and around the shaft was completed.

Shaft 7. — Tunnel lining operations at Shaft 7 were continued until January 28, when dismantling of plant equipment was started. On March 19 the shaft top of pre-cast beams and slabs was placed. Filling and grading over and about the shaft top was completed on April 18. The contractor's force averaged 32 men up to April 18. The average number of persons occupying the camp until it was closed on January 10 was 42, the maximum population being 48 during the week ending December 20, 1930.

Shaft 8. — (Under the supervision of the Coldbrook-Swift Tunnel Division.) At the beginning of the year concreting operations had been completed and the shaft was used for pumping, ventilating and similar purposes.

The total work done and materials furnished under the principal items of Contract 17 are as follows:

Rock excavation in shafts and in tunnel within 50 ft. of shafts	4,788	cu. yds.
Excavation in tunnel except within 50 ft. of shafts	250,331	" "
Shaft and tunnel drainage	41,143	lin. ft.
Forms for preliminary concrete lining, Shaft 8	246	" "
Forms for concrete lining in tunnel	41,168	" "
Concrete masonry in shafts	1,947.5	cu. yds.
Concrete masonry in tunnel	87,526	" "
Concrete masonry not in shafts or tunnel	467	" "
Permanent timbering in tunnel	1.84	M ft. B. M.
Temporary timbering in tunnel	3.44	M ft. B. M.
Portland cement	119,322	bbls.
Earth excavation	822	cu. yds.
Rock excavation except in shafts and tunnel	773	" "
Refilling and embankment	1,645	" "
Caring for and setting metal-work furnished by the Commission	81,583	lbs.
Caring for and setting cast iron lining for Shaft 8	511,267	"

Average "Breakage", Contracts 14 and 17. — In fixing the thickness of concrete lining at any cross-section of the tunnel, a line called the "A" line was established beyond which no points of rock were allowed to project. This line therefore fixed the minimum thickness of the concrete lining and in general was 3 inches from the neat face of the concrete on the side walls and invert and 8 on the arch. A line called the "B" line was also defined as 12 inches outside the "A" line for side walls and arch, and 2 inches outside for the invert. The "B" line is generally the payment line for both excavation and concrete and is intended to represent a fair average of the irregular rock breakage with reasonable care in the prosecution of the work. The actual breakage of rock beyond the "A" line for the side walls and arch averaged 11⅜ inches on Contract 14, 9¾ inches on Contract 17 and 10⅝ inches for both contracts.

Concrete Lining of Tunnel— Contracts 14 and 17. — The contractor continued tunnel lining operations, using for the side walls and arch the two complete tunnel concrete plants designated as plants "A" and "B" in the last annual report. At the beginning of the year plant "A" was headed westerly towards Shaft 4 and concreting of side walls and arch had reached a point 126 feet east of the center line of the shaft. Commencing January 24 concrete for the side walls and arch in this short remaining distance of 115 feet, not including the shaft bottom, was mixed on the surface and delivered by concrete car and chute to the concrete gun at plant "A", this section being completed on January 29. The plant was then turned around at the foot of the shaft and the side walls and arch in the length of 40 feet remaining west of the shaft were concreted in a similar manner with concrete mixed on the surface on February 1 and 2. This completed all the side walls and arch concreted by plant "A", and left only 22 feet at the shaft bottom, 11 feet either side of the center line.

At the beginning of the year plant "B" was headed easterly towards Shaft 2

and concreting of side walls and arch had reached a point 609 feet west of the shaft. It continued easterly 507 feet to 102 feet west of Shaft 4, reaching this point on December 6, 1930. The side walls and arch in the 128 feet remaining east of Shaft 2, were then poured with concrete mixed on the surface, December 15 to January 23, inclusive. The plant was then turned around and commencing January 27 the side walls and arch in the 91 feet, not including the shaft bottom, remaining just west of Shaft 2 were concreted in a similar manner with concrete mixed on the surface, this section being completed January 30. This completed all the side walls and arch concreted by plant "B", and left only 22 feet at the shaft bottom, 11 feet either side of the center line.

The lining of tunnel invert was continued from Shafts 2, 4 and 7. Continuing on December 1, 1930, from a point 7,302 feet west of Shaft 7, the work progressed 7,291 feet easterly to 11 feet west of the center line of the shaft, reaching this point January 8; and starting January 9, 313 feet east of the shaft, the work progressed westerly the short remaining distance of 302 feet to 11 feet east of the center line of the shaft.

Continuing on December 1, 1930, from a point 4,778 feet west of Shaft 4, the work progressed 4,305 feet easterly to 473 feet west of the shaft, reaching this point December 17, and starting again January 21 continued easterly 352 feet to 121 feet west of the center line of the shaft, reaching this point January 23; and starting December 14, at a point 9,466 feet east of the shaft the work progressed 9,380 feet westerly to a point 86 feet east of the center line of the shaft, reaching this point January 30.

Starting December 8, 1930, at a point 9,376 feet east of Shaft 2, the work progressed 9,365 feet westerly to 11 feet east of the center line of the shaft, reaching this point February 7; and starting December 20, at a point 8,520 feet west of the shaft, the work progressed 8,504 feet easterly to 16 feet west of the center line of the shaft, reaching this point February 3.

The remaining short distances at the shaft bottoms, 27 feet at Shaft 2, 207 feet at Shaft 4, 38 feet at Shaft 5, and 22 feet at Shaft 7, were concreted together with the short gaps in the side walls at the shaft bottoms being completed February 7, 1931. The following summary of progress of invert lining completes the data given in similar form in the last annual report.

Progress of Invert Lining

Aggregate from Crushing Plant at	Total Feet Concreted in One Stretch	Average Feet Per Day
Shaft 2	8,504	185
	9,365	151
	27	
Shaft 4	4,305	253
	9,380	195
	352	117
	207	103
Shaft 5	38	
Shaft 7	7,291	187
	302	101
	22	
Total Invert completed in Year Ending Nov. 30, 1931	39,793	
Total Invert completed in Year Ending Nov. 30, 1930	34,520	
Total Invert completed in Year Ending Nov. 30, 1929	526	
Well at bottom of Shaft 8	31	
Total Length included in Contracts 14 and 17	74,870	

The contractor's plant equipment and the methods used in lining the tunnel are fully described in the last annual report.

Contract 22. — The first work done by F. A. Mazzur Co., Inc., Boston, Mass., under Contract 22, for furnishing and installing the tunnel unwatering pump in Shaft 1 of the Wachusett-Coldbrook tunnel in the town of West Boylston, was the installation, on March 10, of a 16-inch valve on the discharge line at the bottom of the pump shaft. On July 23 the single stage centrifugal pump of 20 million gallons daily capacity was delivered and on the following day was lowered into the pump shaft. The 900-horsepower motor of the pump arrived on July 24 and on the following day was lowered into the shaft and coupled to the pump. On August 8 the air blower was installed. The installation was completed on September 11, when tests were begun in connection with the unwatering and inspection of the tunnel. Tests were completed on Septem-

ber 19. At the end of the year the only work remaining to be done was the removal of the motor to the top of the shaft and the filling of the pump with oil for protection during the expected long period of disuse.

The value of work included in contract estimates to October 26, the date of the latest estimate, was $12,593.81, of which 90% was approved for payment.

The contractor's force averaged 1 man for the 3 months.

Contract 25. — Contract 25, for constructing the superstructure of the Wachusett outlet building of the Wachusett-Coldbrook Tunnel at Shaft 1 in the town of West Boylston, was continued in force throughout the year. At the beginning of the year the work had been about 25% completed and work was in progress on laying the masonry walls with tile and brick facing. The walls were completed about the middle of December. Laying the ashlar masonry facing of the north abutment of the circular dam across the Quinapoxet River was also in progress and was finished except for the coping, on January 5. All operations were then suspended for the winter. Work was resumed about the first of April. The installation of gypsum roof slabs was begun on April 25, and laying of the slate roof on May 30. The roof was completed on June 27. Miscellaneous work continued during the summer and on September 19 removal of equipment and general cleaning up was started. At the end of the year the entire work on this contract had been practically completed.

The value of work included in contract estimates to November 2, the date of the latest estimate, was $60,312.15, of which 90% was approved for payment. The contractor's force up to October 31, excepting about 2 months during the winter when operations were suspended, averaged 3 men, the maximum being 32 during the week ending December 13, 1930.

Contract 26. — Contract 26, for furnishing and installing power and lighting wiring and electrical equipment at the Wachusett outlet works of the Wachusett-Coldbrook tunnel at Shaft 1 in the town of West Boylston, was continued in force throughout the year. At the beginning of the year the contract had been nearly completed except for miscellaneous work required from time to time in connection with the work of Contracts 22 and 25. Work was resumed on April 13, with the construction of an underground armored cable from the transformer station south of Holden Street to the outlet building, and power was turned on in the building on April 18.

The value of work included in contract estimates to November 10, the date of the latest estimate, was $9,888.62, of which 90% was approved for payment. The contractor's force up to November 7, excepting 4 months during the winter when operations were suspended, averaged 1 man, the maximum being 2.

Contract 28. — Contract 28, for grading the grounds of the Ware River intake building in the town of Barre, was executed August 17 with Anthony Ross & Son, Lexington, Mass. Work was started on September 9 with the excavation for stone wall foundations and delivery of stone. The work was carried on continuously and at the end of the year was practically completed, with the exception of capstones on the stone wall and seeding and grassing. Loam for soil dressing was stripped by a ½-cubic yard gasoline shovel from land of the Commonwealth in Coldbrook, and delivered by truck. Stone for the wall was also obtained from land of the Commonwealth except the capstones. Base stone for the driveway was obtained from the surplus coarse aggregate pile at Shaft 7 of the Wachusett-Coldbrook tunnel.

The value of work included in contract estimates to November 16, the date of the latest estimate, was $5,042.70, of which 90% was approved for payment. The contractor's force up to November 14 averaged 9 men, the maximum being 14 during the week ending October 31.

Contract 29. — Contract 29, for grading the grounds in the vicinity of the Wachusett outlet building in the town of West Boylston, was executed August 17 with Anthony Ross & Son, Lexington, Mass. On August 19 the work of grading was commenced with a ½-cubic yard gasoline shovel. At the end of the year the work was practically completed, with the exception of capstones on the stone wall and a small amount of seeding. Loam for soil dressing was obtained from storage piles and settling basin dikes placed under Contract 14. Stone for the wall was also obtained from land of the Commonwealth except the capstones.

Contract 31. — Head House at Shaft 4. Tunnel Spoil Bank in Rear of Building.

Contract 24. — Ware River Intake Building at Shaft 8, Showing also Diversion Dam Constructed under Contract 19 and Grading of Grounds under Contract 28. Tracks of Ware River Branch of Boston & Albany Railroad in Foreground.

The value of work included in contract estimates to November 16, the date of the latest estimate, was $9,398.75, of which 90% was approved for payment. The contractor's force up to November 21, averaged 9 men, the maximum being 21 during the week ending September 5.

Contract 31. — Contract 31, for constructing the superstructure of the head house at Shaft 4 of the Wachusett-Coldbrook tunnel in the town of Rutland, was executed August 26, with E. D. Ward Co. of Worcester, Mass. Work was started on September 10 with the laying of the masonry walls of the building, the foundations having been prepared under Contract 14. Structural steel for the roof was delivered on October 1 and erection completed on October 25. The roof of slate shingles on plank was completed November 8. At the end of the year practically the entire work was completed with the exception of a small amount of seeding.

The value of work included in contract estimates to October 10, the date of the latest estimate, was $2,719.50, of which 90% was approved for payment. The contractor's force up to November 21 averaged 5 men, the maximum being 8 during the week ending October 10.

Coldbrook-Swift Tunnel Division — Hardwick Office

The Coldbrook-Swift Tunnel Division was in charge of the construction of the Coldbrook-Swift tunnel, an extension to the Swift River of the Wachusett-Coldbrook tunnel. It also continued in charge of the construction to completion at Shaft 8, of the Wachusett-Coldbrook tunnel, and until October 1, or until practical completion, the construction of the Ware River intake works. In general the completion after October 1 of all work in the vicinity of Shaft 8 including the intake works was turned over to the Holden Office of the Wachusett-Coldbrook Tunnel Division, as was also all work in connection with improvements in the Ware River watershed.

Office Work

Tunnel, shaft and intake sections were plotted and excavation and masonry volumes computed therefrom. Semi-monthly estimates were prepared for Contracts 17 and 20, monthly estimates for Contracts 19, 24 and 27, and final estimates for Contracts 17, 19, 24 and 27. Topographic maps were made of the area along the Ware River extending above the state highway bridge in Coldbrook. Work was continued on maps and capacity curves of various ponds on the watershed including mill ponds on the river below the intake works. Daily rainfall and temperature records were continued at the White Valley meteorological station.

Field Work

Lines and grades were given for construction work on Contracts 17, 19, 20, 24 and 27. The work included the location of an access road at Shaft 10 and a relocation of the existing highway near Shaft 12. About 400 acres of topography were taken along the Ware River both above and below the intake. The triangulation of the Ware River watershed was continued to include the upper Ware and Burnshirt rivers. Real estate surveys were made of about 40 acres on the Ware River watershed and other properties along the line of the Coldbrook-Swift tunnel. Weekly observations of water color samples along the Ware River and its tributaries were continued. The State Department of Public Health cooperated in the analysis of samples of drinking water used in the different contractors' camps, and extended to the Coldbrook-Swift tunnel its investigation of mosquito breeding with reference to the prevention of malaria. Samples of concrete for testing were taken, and records were continued of the amount of cement used and required to be used at all points of the work. Geological investigations were commenced in connection with the Coldbrook-Swift tunnel construction.

Collection of Stream Flow and Water Power Data

The reading of staff gages, set to determine the head at various water power plants on the Ware, Swift and Chicopee rivers and the fluctuations in the level of the ponds on the Ware and Quaboag river watersheds, was continued. The recording gaging stations at White Valley and Bircham Bend were continued

and an additional station established at Red Bridge on the Chicopee River. Current meters were rated from time to time as required.

Investigations of the quality of the water in the Ware River both above and below the intake works were continued in conjunction with the laboratory at Enfield, the principal work of this office being the determination of the necessary hydraulic data.

Construction by Force Account

Work on watershed improvement was continued by force account with labor employed and supervised by the division office until about November 1 when the supervision of this labor force was taken over by the Holden Office of the Wachusett-Coldbrook Tunnel Division. The work consisted largely of cleaning up the premises of buildings in Coldbrook, burning stumps and other debris along the Ware River and on the shores of ponds, and constructing property fences.

Progress of Contracts

Contract 17. — The construction work on the Wachusett-Coldbrook tunnel from Shaft 8 was continued to completion under the supervision of the Hardwick Office and is hereinbefore described.

Contract 19. — Contract 19, for constructing the low diversion dam and the substructure of the building for the Ware River intake works at Shaft 8 of the Wachusett-Coldbrook tunnel in the town of Barre was continued to completion, the work done during the year consisting mainly of plumbing, steam fitting, wiring and painting.

The value of work included in contract estimates during the year was $32,901.28, the final estimate, dated March 9, being for $285,580.49. The contractor's force averaged 5 men for 13 weeks, the maximum being 9 for the week ending January 10.

The total work done and materials furnished under the principal items of Contract 19 are as follows:

Earth excavation (below elevation 642)	4,768 cu. yds.
Earth excavation (above elevation 642)	4,756 " "
Rock excavation	1,952 " "
Earth filling and embanking of pervious material	10,907 " "
Riprap	1,335 " "
Portland cement	9,968 bbls.
Concrete masonry	6,672 cu. yds.
Dimension stone masonry	127 " "
Ashlar masonry	526 " "
Steel for reinforcing concrete	202,375 lbs.

Contract 20. — Contract 20 is for the construction of the Coldbrook-Swift tunnel through the towns of Barre, Hardwick and Greenwich and extends 10.39 miles from the end of the Wachusett-Coldbrook tunnel, completed under Contract 17, to the intake from the east branch of the Swift River at Quabbin Lake in the town of Greenwich. The contract was executed April 23 with Wenzel & Henoch Construction Company of Milwaukee, Wis.

Work was begun immediately on April 23 with the clearing of the tunnel right of way for the construction of an electric transmission line to supply electricity to the four shafts from the South Barre substation of the New England Power Company. At the end of the year about 8 per cent of the value of the work was completed, including excavation of all four construction shafts, lining of Shafts 9, 10 and 11, excavation of about 2,612 feet of tunnel and practical completion of excavation of the low level intake cut to the tunnel portal at Quabbin Lake. A length of 52,234 feet of tunnel remains to be excavated under this contract. The contractor employed local physicians who made weekly reports on the health of his employees and on the sanitary condition at each of his camps.

The value of work included in contract estimates to November 26, the date of the latest estimate, was $380,012.61, of which 90% was approved for payment.

Shaft 9. — Work was started June 3 on the construction of camp and plant buildings. The camp buildings include an emergency hospital, 3 bunk houses, wash house, general office, engineer's office and mess hall. The buildings at the shaft include compressor and hoist house, tool house and blacksmith's shop. Shaft excavation was started on July 1. A stiff leg derrick was completed and

put into operation the next day. It took about a week to uncover bed rock in the shaft, the first blast in rock being fired on July 9. The first concrete for shaft lining was poured on July 21. The tunnel headings were turned on August 28. Construction of the head frame was started on August 10 and the partly completed frame was moved over the shaft about September 1 and used to raise and lower buckets until October 5 when work was suspended to allow the installation of hoist skips and other tunnel driving equipment. Tunnel driving was resumed on October 29. Commencing November 3 excavation by the top heading and bench method was discontinued and the full face method used.

The head frame is designed to raise and lower balanced skips in approximately one half the area of the shaft leaving the other half open for a bucket hoist. A platform at the top of the shaft allows men to enter and leave the skips. When the skips are raised to the top of the head frame they are dumped automatically into a bin and thence to cars for delivery to the spoil bank. When the head frame is completed the muck from the skips will fall over a grating of steel bars which will reject to the spoil bank stones over 6 inches in size. Stones under 6 inches will drop into a rotary screen from which material graded up to 2 inches in size will pass by way of belt conveyors directly to the storage piles of concrete aggregates for future use in tunnel lining. Stones 2 to 6 inches in size will be discharged directly into crushers. The entire screen and crusher installation will be self-contained at the head frame. Any rock excavated from the tunnel that is unsuitable for concrete aggregates will be by-passed directly to the tunnel spoil bank. Electric locomotives are used in the tunnel and a battery charging station was excavated in the side of the tunnel near the foot of the shaft. The rock from tunnel excavation is loaded into 3-yard, side-dump cars by a mucking machine. At the bottom of the shaft these cars are upturned by a small air hoist to fill the 3-yard hoist skip.

The average weekly progress of tunnel excavation to October 5, with the bucket hoist, was 39.1 feet easterly and 40.6 feet westerly with a maximum progress of 56 feet in the east heading and 55 feet in the west heading for the week ending September 18. Commencing October 29, the average weekly progress was 65 feet easterly and 72 feet westerly. The total length of tunnel excavated for Shaft 9 at the end of the year was 574 feet easterly and 575 feet westerly, making a total of 1,149 feet. The contractor's force averaged 41 men since June 3, the maximum being 78 during the week ending November 21. The average number of persons occupying the camp since July 18 was 8, the maximum population being 16 during the week ending November 7.

The principal items of plant at Shaft 9 were as follows:

3 Air compressors with a combined capacity of 1,850 cu. ft. per min., the largest having a capacity of 750 cu. ft. per min.
1 Main hoist
1 Auxiliary hoist
1 Blower
2 Mucking machines and miscellaneous mucking and spoil removal equipment
8 Pumps, the largest of which is rated at 150 gals. per min. under 225-ft. head driven by air pressure
1 Head frame with balanced 3-yard skips
Cars, machine shop equipment, drilling equipment, etc.

Miscellaneous Construction Data, Shaft 9

Total depth of shaft	200 ft.
Depth of earth	9 ft.
Depth of rock	191 ft.
Work begun	June 3, 1931
Earth excavation begun	July 1, 1931
Rock excavation begun	July 9, 1931
Maximum depth of rock excavated in one week	33 ft.
Shaft concrete lining begun	July 21, 1931
Tunnel excavation started	August 28, 1931

Shaft 10.—Work was started June 10 on the clearing of the right of way of an access road to the shaft. By July 13, this road was finished sufficiently for hauling materials and equipment to the shaft site. Camp and plant buildings were constructed similar to those at Shaft 9. Shaft excavation was started on June 22, using a stiff leg derrick. Bed rock was uncovered on August 6. The first concrete for shaft lining was poured on August 13. The tunnel headings were turned on November 24. Construction of the head frame was started on October 19.

The total length of tunnel excavated at Shaft 10 at the end of the year was 20 feet easterly and 24 feet westerly, making a total of 44 feet. The contractor's force averaged 37 men since June 22, the maximum being 51 during the week ending August 8. The average number of persons occupying the camp since August 22 was 6, the maximum population being 10 during the week ending September 19.

The principal items of plant at Shaft 10 were as follows:

3 Air compressors having an aggregate capacity of 1,800 cu. ft. per min., the largest having a capacity of 750 cu. ft. per min.
1 Main hoist
1 Auxiliary hoist
1 Blower
7 Pumps, the largest of which is rated at 150 gals. per min. under 450-ft. head, driven by air pressure
Cars, machine shop equipment, drilling equipment; etc.

Miscellaneous Construction Data, Shaft 10

Total depth of shaft	408 ft.
Depth of earth	34 ft.
Depth of rock	374 ft.
Work begun	June 10, 1931
Earth excavation begun	June 22, 1931
Rock excavation begun	August 6, 1931
Maximum depth of rock excavated in one week	43 ft.
Shaft concrete lining begun	August 13, 1931
Tunnel excavation started	November 24, 1931

Shaft 11.— Work was started June 21 on the construction of camp buildings and the installation of equipment. Electric transformers were installed and power made available on July 7. Shaft excavation was started on July 15. Bed rock was uncovered on July 20. The first concrete for shaft lining was poured on July 28. The tunnel headings were turned on September 10. Construction of the head frame was started on July 29 and the partly completed frame was moved over the shaft on October 4. Tunnel excavation was continued by the top heading and bench method until October 30 when it was suspended to allow the installation of hoist skips and other tunnel driving equipment similar to that used at Shaft 9 and hereinbefore described. Tunnel driving was resumed on November 19.

The average weekly progress of tunnel excavation to October 30 was 42.0 feet easterly and 40.6 feet westerly with a maximum progress of 52 feet in the east heading and 57 feet in the west heading for the week ending October 16. The total length of tunnel excavated from Shaft 11 at the end of the year was 423 feet in each heading, making a total of 846 feet. The contractor's force averaged 37 men since June 21, the maximum being 68 during the week ending November 28. The average number of persons occupying the camp was 6, the maximum population being 11, during the week ending November 11.

The principal items of plant at Shaft 11 were as follows:

3 Air compressors having an aggregate capacity of 1,850 cu. ft. per min., the largest having a capacity of 750 cu. ft. per min.
1 Main hoist
1 Auxiliary hoist
1 Blower
4 Pumps, the largest of which is rated at 170 gals. per min. under 225-ft. head, driven by air pressure
Cars, machine shop equipment, drilling equipment, etc.

Miscellaneous Construction Data, Shaft 11

Total depth of shaft	275 ft.
Depth of earth	24 ft.
Depth of rock	251 ft.
Work begun	June 21, 1931
Earth excavation begun	July 15, 1931
Rock excavation begun	July 20, 1931
Maximum depth of rock excavated in one week	44 ft.
Shaft concrete lining begun	July 28, 1931
Tunnel excavation started	Sept. 10, 1931

Shaft 12 and Swift River Intake.— Work was started June 21 on the clearing of the camp site and the excavation of top soil at the shaft site. Electric transformers were installed and power made available on July 7. Bed rock was uncovered in the shaft on July 14. A stiff leg derrick was erected during the week ending July 27. The public highway near the site of the shaft was re-

located and traffic diverted on July 29. A preliminary concrete lining in the upper portion of Shaft 12 was poured commencing August 24. The tunnel headings were turned on September 16. Tunnel excavation in the west heading was discontinued on October 9, but continued in the east heading until October 20, when it was suspended to allow the installation of hoist skips and other tunnel driving equipment similar to that used at Shaft 9 and hereinbefore described. Tunnel driving was resumed on November 19.

Excavation of the lower intake cut was started August 1, using a 1-yard gasoline shovel and motor trucks, the top soil being placed in storage piles. The trench was practically completed on November 30, except for riprap on the side slopes. Earth and rock excavation from the lower intake cut was spread about 2 feet thick over the swamp area along the shore of Quabbin Lake. The entire swamp area south of the future intake channel was completely covered and filling on the swamp area north of the channel was in progress. Tunnel spoil also was placed on this area commencing September 18, previous to which it has been used for constructing roads from the shaft to the spoil area along Quabbin Lake and for levelling an area near the shaft to be used for the storage of concrete aggregates.

The average weekly progress of tunnel excavation was 39.2 feet westerly until October 9 and 41.8 feet easterly until October 20, with a maximum progress of 82 feet in the east heading and 15 feet in the west heading for the week ending October 16. The total length of tunnel excavated from Shaft 12 at the end of the year was 406 feet easterly and 167 feet westerly, making a total of 573 feet. The contractor's force averaged 44 men since June 21, the maximum being 61 during the weeks ending October 10 and November 28. The average number of persons occupying the camp was 17, the maximum population being 21, during the week ending October 10.

The principal items of plant at Shaft 12 were as follows:

2 Air compressors having an aggregate capacity of 1,300 cu. ft. per min., the largest having a capacity of 750 cu. ft. per min.
1 Main hoist
1 Auxiliary hoist
1 Blower
6 Pumps the largest of which is rated at 150 gals, per min. under 450-ft. head, driven by air pressure
Cars, trucks, machine shop equipment, drilling equipment, etc.

At the lower intake:

1 1-cubic-yard gasoline-driven shovel
4 Trucks
1 Pump, 30 horsepower

Miscellaneous Construction Data, Shaft 12

Total depth of shaft	90 ft.
Depth of earth	4 ft.
Depth of rock	86 ft.
Work begun	June 21, 1931
Earth excavation begun	June 21, 1931
Rock excavation begun	July 14, 1931
Maximum depth of rock excavated in one week	19 ft.
Shaft concrete lining begun	August 24, 1931
Tunnel excavation started	Sept. 16, 1931

The total work done and materials furnished to date under the principal items of Contract 20 are as follows:

	Shaft 9	Shaft 10	Shaft 11	Shaft 12 and Intake
Earth excavation for shafts (cu. yds.)	84	318	225	*
Rock excavation in shafts and in tunnel within 50 ft. of shafts (cu. yds.)	2,310	2,997	2,660	1,445
Excavation in tunnel, except within 50 ft. of shafts (cu. yds.)	6,217	—	4,170	3,723
Shaft and tunnel drainage (lin. ft.)	392	298	369	163
Earth excavation in open cut (cu. yds.)	—	2,500	1,803	29,364
Rock excavation in open cut (cu. yds.)	—	435	106	1,409
Forms for concrete linings of shafts (lin. ft.)	178	397	258	—
Concrete masonry in shafts (cu. yds.)	400	929	611	—
Concrete masonry not in shafts or tunnel cu. yds.)	—	—	1	132
Portland cement (bbls.)	753	1,334	898	439

*Included in item, "Earth excavation in open cut."

Contract 24. — Contract 24, for constructing the superstructure of the building for the Ware River intake works at Shaft 8 of the Wachusett-Coldbrook tunnel in the town of Barre was continued to practical completion on October 10. Work was discontinued for the winter from about January 1 until April 6. Previous to this discontinuance the completed portions of the stone masonry walls were covered to protect them from the weather during the winter months and a cement wash was applied to all exposed steel work. The building walls were completed on May 29. The bridge crane was erected on May 1, and on June 17 was tested and put to immediate use in the shaft and valve pit. The laying of gypsum roof slabs was completed on July 10 and the slate roofing about August 1.

The value of work included in contract estimates during the year was $61,439.29 or a total to October 22, the date of the latest estimate, of $69,834.40, of which 90% was approved for payment. The contractor's force averaged 10 men for 30 weeks, the maximum being 26.

Contract 27. — Contract 27, for filling with earth, areas along the banks of the Ware River in the town of Barre, was continued to completion in December 1930.

The value of work included in contract estimates during the year was $2,945.51, the final estimate, dated December 20, 1930, being $4,395.51. The contractor's force averaged 10 men for 2 weeks.

Swift River Reservoir Division — Enfield Office

The Swift River Reservoir Division continued in charge of the field work in the Swift River valley in connection with the proposed Swift River Reservoir. In this connection the division continued its topographic surveys of the proposed reservoir basin, general surveys of real estate required for reservoir purposes, preparation of maps of all surveys, cemetery removal work and studies of soils and other materials with reference to their suitability for use in the construction of the proposed dam and dike. The division was also in charge of construction work for a new cemetery development, highway relocation, and the river diversion tunnel and other preliminary work at the site of the main dam and dike.

Miscellaneous Office Work

Semi-monthly estimates for Contract 21 and monthly estimates for Contracts 23, 30, 32 and 34 were prepared. Plans of the relocated Ware-Belchertown highway were prepared for contract use and also for submission to the State Department of Public Works and the County Commissioners of Hampshire County. The new route leaves the existing highway, Route No. 109, at a point about 0.8 mile east of Belchertown Center, passes south of the site of the main dam of the Swift River Reservoir and joins the existing highway again at a point about 0.2 mile west of Beaver Brook, thus substituting 5¼ miles of new highway for 7½ miles of the existing route through Enfield. The new highway will have a 24-foot bituminous macadam surface with 3-foot gravel shoulders.

Real estate plans were prepared along the line of the Coldbrook-Swift tunnel within the Swift River watershed and along the line of the relocated Ware-Belchertown highway. Photographs of the progress of construction carried on under the supervision of this and other divisions, were taken by this division. Topographic plans were prepared of the site of the proposed new cemetery development. Meteorological records were continued at Enfield.

Miscellaneous Field Work

Lines and grades were given for construction work on Contracts 21, 23, 30, 32 and 34. Test pits were dug by labor employed on force account in connection with the investigations of materials for use in the construction of the main dam and dike. Surveys were completed for the relocation of a porton of the Ware-Belchertown highway under Contract 21, and test pits were dug by labor employed on force account to determine the occurrence of ledge and boulders and the character of excavations to be made.

Reservoir — General

Topography. — During the year, 2,155 acres of topography within and adjacent to the proposed reservoir were surveyed, making a total to date of 25,970

acres or 40.6 square miles. During the year 1,550 acres of topography were mapped, making the total to date 25,130 acres. Of this total, tracings have been made covering 21,065 acres. Studies were made of the general problem of highway relocation.

Real Estate. — Additional property described in applications by owners for sale of real estate was located and sketches made showing the approximate location. Comprehensive real estate surveys and analyses and descriptions of deeds were continued. Tables were compiled of all properties in the towns of Enfield, Greenwich and Dana. Real estate surveys during the year cover 920 acres, making a total to date of 58,310 acres or 91.11 square miles. Of this total, 57,495 acres have been plotted at a scale of 1 inch=200 feet and final tracings have been made covering a total of 39,701 acres. Cruising of timbered areas by standard forestry methods was continued.

Photography. — The photographing of buildings and cemetery lots within the area to be affected by the proposed reservoir and the making of record prints were continued. During the year 16 photographs of buildings, 194 of cemetery lots and 207 of the progress of construction carried on under the supervision of this and other divisions were taken. The work of photographing monuments and headstones in cemetery lots has been practically completed.

Cemetery Removals. — No general removal of bodies from within the proposed reservoir has been undertaken but removals at the request of interested parties continued. During the year 43 releases of rights in cemetery lots were executed by interested parties. The removal of bodies, headstones and monuments has been done by this division with labor engaged directly for this work. During the year 126 bodies were removed from 43 lots in various cemeteries in the area to be affected by the reservoir together with 65 headstones and 26 monuments, making a total removed to date of 527 bodies, 235 headstones and 95 monuments. The work of removing and resetting monuments has been facilitated by the use of a platform body truck equipped with power winch, cable and tripod.

Fire Protection. — The fire fighting equipment housed at Enfield was continued in readiness for service at all times. Five assistants in the division office were reappointed as deputy forest wardens in each of the towns affected by the reservoir. The equipment and personnel responded during the year to calls for assistance at 10 forest fires which burned over a total area of 233 acres. The apparatus also responded to fires in 10 buildings.

Laboratories

Soil Testing Laboratory. — The work of exploring, collecting, and testing materials to determine their suitability for use in the construction of the proposed main dam and dike was continued. New equipment was added to the laboratory as testing methods were expanded to include new studies and to keep pace with current developments in soil engineering. The investigations included top soils, silt deposits near Mt. Lizzie in Greenwich, extensive deposits of glacial till forming the ground moraine overburden on the west side of Beaver Brook valley north of the dike site, and similar deposits on the west side of the Swift River valley north of the dam site. In connection with the construction of the Swift River diversion works, tests were made of top soils to be stripped from affected areas and used in the impervious portions of the cofferdams.

Chemical and Bacteriological Laboratory. — The collecting and analyzing of water samples in preparation for records and reports were continued in cooperation with the Headquarters Office and with assistants from the Coldbrook-Swift Tunnel Division.

Progress of Contracts

Contract 21. — Contract 21, for constructing a relocated portion of the Ware-Belchertown highway in the towns of Ware and Belchertown was executed on July 20 with The Lane Construction Corp. of Meriden, Conn. On July 29 work was started on the installation of a 10-car siding at the West Ware Station of the Athol Branch of the Boston & Albany Railroad. On August 5 the Contractor commenced the work of clearing along the line of highway and installing culverts. On August 14 one steam shovel started excavation at the Belchertown end. At the end of the year seven shovels were engaged on the work, about

70% of the drainage was installed and about 80% of the excavation and embankment completed to subgrade. For approximately 9,600 feet at the Belchertown end gravel base was placed in a condition for winter use by the public through the section that most affects existing highways. On August 16 construction work at the bridge across the Swift River was started. Steel sheet piling was driven around the westerly pier and abutment as a cofferdam inside of which wood sheeting was driven for the footings. For the easterly abutment wood sheeting protected by sand bags was driven as a cofferdam. At the end of the year the entire westerly abutment and pier and the footing of the easterly abutment had been poured.

The value of work included in contract estimates to November 16, the date of the latest estimate, was $56,682.83, of which 90% was approved for payment. The contractor's force averaged 81 men for 16 weeks, the maximum being 132 during the week ending November 14.

The principal items of plant were as follows:

4 Steam shovels
3 Gasoline shovels
6 Bulldozers
4 Road rollers
2 Road graders
4 Tractor trucks
8 Gasoline dump trucks

The total work done and materials furnished to date under the principal items of Contract 21 are as follows:

Roadway earth excavation	51,110 cu.yds.
Bridge excavation	1,140 " "
Ledge excavation	4,758 " "
Reinforced cement concrete masonry	353 " "
Gravel borrow	6,873 " "
Rubble concrete masonry	590 " "
Trench excavation	1,837 " "

Contract 23. — Contract 23, for making borings in the towns of Belchertown, Enfield, Ware, Greenwich and Hardwick continued in force throughout the year. The work was practically confined to the exploration of overburden in the vicinity of the main dam and dike sites.

The value of work included in contract estimates during the year was $8,892.49 or a total to November 10, the date of the latest estimate, of $19,424.07, of which 90% was approved for payment. The Contractor had one drilling rig in operation during the year and employed an average of 2 men.

Contract 30. — Contract 30, for constructing the stream control works at the main dam of the Swift River Reservoir in the towns of Belchertown, Enfield and Ware, was executed August 1 with the Northern States Contracting Co. of St. Paul, Minn. The work includes in addition to the 30-foot rock tunnel 960 feet long, with approach and discharge channels, the partial construction of cofferdams which will form the upstream and downstream toes of the main dam. On August 14 the work of clearing the site was started. On August 17 work was started on the construction of an electric transmission line from existing lines across Quabbin Hill in Enfield. The Contractor installed a 4-car siding adjacent to the Athol Branch of the Boston & Albany Railroad, a short distance above the downstream cofferdam and erected a temporary bridge on timber bents across the Swift River to provide access to the west side. On August 23 stripping of top soil from the site of the downstream cofferdam east of the river was started with a gasoline shovel, on August 27 a second shovel started similar stripping west of the river, and on September 1 a third started on the site of the upstream cofferdam. Two of these shovels then proceeded to excavate the discharge channel and the third to excavate the upstream approach channel.

Materials from the excavations were hauled in trucks to the cofferdams or placed in a storage pile for use later as concrete aggregate. Suitable top soil was stored and used in constructing the impervious blanket on the upstream cofferdam. Materials placed in the cofferdams were spread by bulldozers in 6-inch layers, wetted and rolled by 14-ton gasoline road rollers, equipped with bands on the rear rollers. Boulders too large to be placed in this manner were placed in the cofferdams by puddling, with the result that all heavy material was retained in the cofferdams, which will later become the toes of the main

dam. At the end of the year the portion of the downstream cofferdam included in the contract had been brought to the required grade and that of the upstream cofferdam to within 5 feet of the required grade, except for the portion adjacent to the stream control conduit. In the outlet channel about 40,000 cubic yards remained to be excavated and the bed rock at the downstream tunnel portal was uncovered to an elevation 1 foot below the springing line of the tunnel arch. Excavation in the upstream approach channel was about 80% completed. Plant for tunnel excavation was practically complete at the end of the year.

The value of work included in contract estimates to November 10, the date of the latest estimate, was $65,957.50, of which 90% was approved for payment. The contractor's force averaged 38 men, with a maximum of 64. The maximum total output of the 3 shovels in any 10-hour day was 3,950 cubic yards. The maximum number of trucks used was 11.

The principal items of plant equipment were as follows:

3 Gasoline shovels
1 Electric shovel (for the tunnel)
3 Caterpillar bulldozers
2 14-ton rollers
10 Trucks
4 Air compressors having an aggregate capacity of 2.575 cu. ft. per min.
1 Portable compressor having a capacity of 220 cu. ft. per min.
4 Pumps, drilling equipment, etc.

The total work done and materials furnished to date under the principal items of Contract 30 are as follows:

Removal of soil	9,300 cu. yds.
Earth excavation in open cut	170,800 " "
Rock excavation in open cut	1,990 " "
Impervious embanking	2,350 " "
Refilling and embanking compacted in 6-inch layers	89,350 " "
Other refilling and embanking	41,900 " "

Contract 32. — Contract 32, for constructing two exploratory caissons, one at the main dam and one at the dike of the Swift River Reservoir in the towns of Enfield and Ware was executed September 16 with the Dravo Contracting Co. of Pittsburgh, Pa. Work of plant installation at the dam site was started on September 25 and excavation of open cut on October 13. Excavated material was hauled by truck to a spoil area at the downstream toe of the proposed main dam. A connection for power was made to the transmission line serving Contract 30. By October 30 the caisson shoe had been erected and concrete forms placed for pouring to a height of 16 feet. After concreting reached a height of 31.5 feet above the cutting edge, excavation in the caisson was started by the open dredging method.

At the end of the year concrete had been poured to a height of 73 feet above the cutting edge and the caisson had been sunk by open dredging to a depth of 35 feet, out of a total estimated required depth of 87 feet. Plant for sinking the caisson under compressed air was installed. Work at the dike site consisted only in clearing, repair of access road and installation of equipment foundations.

The value of work included in contract estimates to November 16, the date of the latest estimate, was $12,497.50, of which 90% was approved for payment. The contractor's force averaged 18 men, the maximum being 29 during the week ending November 21.

The principal items of plant were as follows:

1 Steel derrick, 90-ft. boom
2 Air compressors, each with a capacity of 888 cu. ft. per min. and driven by 152 horsepower motor
2 Air receiver tanks, 3.5 ft. x 10.8 ft.
1 1-cubic-yard clam shell bucket
1 Orange peel bucket
3 Man locks
1 Muck lock
1 Medical lock, 7 ft. x 22.5 ft.
5 Pumps, including 2 in the caisson, each of 1,000 gals. per min. capacity under 120-ft. head
1 1-cubic-yard concrete mixer
Sand and gravel aggregate hoppers, 60-ft. steel tower and chutes
Cars, track, diving apparatus, etc.

Contract 34. — Contract 34, for constructing driveways in a new cemetery development in the town of Ware was executed October 29 with The Lane Construction Corp. of Meriden, Conn. Clearing of the driveway areas was started October 30. On November 4 a ½-cubic yard gasoline shovel started the work of stripping top soil and storing it for later use in covering side slopes. Excavation of the cuts to subgrade was completed on November 23, the material being hauled to the embankment fills in trucks. Gravel surfacing was completed November 25. A concrete box culvert under the entrance road to the cemetery was completed on November 12.

The value of work included in contract estimates to November 20, the date of the latest estimate, was $2,633.92, of which 90% was approved for payment. The contractor's force averaged 8 men, the maximum being 14 for the week ending November 14.

Geological Data

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State." Such information has been prepared for publication in a subsequent report.

List of Drawings and Tables Appended Hereto

Location of Real Estate Acquired for the Swift River Reservoir.
Takings of Real Estate (and Water Rights).
Status of Contracts Completed Prior to Nov. 30, 1930.
Status of Contracts in Progress between Nov. 30, 1930 and Nov. 30, 1931. (2 sheets.)
Key Plan and Profile, Coldbrook-Swift Tunnel.

For General Plan of Metropolitan Water Supply and Key Plan and Profile of Wachusett-Coldbrook Tunnel, see Second Annual Report.

Respectfully submitted,

Frank E. Winsor, *Chief Engineer.*

20 Somerset Street, Boston, Mass.
December 15, 1931.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Administration, *Commissioners' Office:*		
Salaries, Commissioners	$10,500.00	$56,112.80
Salaries, Clerical	10,419.78	49,105.41
General Legal Expense	0.00	1,377.80
Furniture and Fixtures	129.98	2,082.56
Rent and Upkeep	2,321.30	11,553.99
Automobile Purchase	0.00	1,988.90
Automobile Maintenance	323.78	1,601.34
Miscellaneous Expense (undistributed)	1,339.56	8,984.66
Advertising	1,348.77	4,293.59
Printing and Blueprinting	1,862.78	4,644.99
Stationery and Office Supplies	259.94	1,093.12
Postage	102.00	462.55
Total Administration	$28,607.89	$143,301.71
Engineering, *Headquarters Office:*		
Salaries, Engineering	$77,993.10	$393,140.09
Salaries, Clerical	9,539.86	46,678.41
General Consultant Expense	9,275.65	98,973.34
General Legal Expense	36,981.26	53,160.29
Furniture and Fixtures	507.92	11,682.81
Laboratory Equipment	0.00	1,961.00
Laboratory Supplies	0.00	2,071.94
Rental of Equipment	0.00	3,370.02
Engineering Instruments	124.84	974.06
Rent and Upkeep of Boston Offices	10,992.25	51,547.32
Rent and Upkeep of Springfield Laboratory	0.00	3,950.54
Automobile Purchase	0.00	2,675.60
Automobile Maintenance	323.86	2,490.43
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	1,760.16	17,865.28
Printing and Blueprinting	3,883.72	12,086.63
Stationery and Office Supplies	582.42	2,908.62
Postage	195.00	849.58
Total Engineering, Headquarters Office	$152,160.04	$708,690.59
Unassigned:		
Unassigned Supples and Equipment	–$1.73	$643.51
Total Unassigned	–$1.73	$643.51
Total General Overhead	$180,766.20	$852,635.81

Distribution of General Overhead

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Administration:		
Wachusett-Coldbrook Tunnel	$9,454.57	$59,413.86
Coldbrook-Swift Tunnel	3,517.23	10,870.73
Swift River Reservoir	10,516.22	59,229.49
Main Dam and Dike	5,097.35	5,097.35
Southern Sudbury Emergency Supply	22.52	8,690.28
Total Administration	$28,607.89	$143,301.71
Engineering, *Headquarters Office:*		
Wachusett-Coldbrook Tunnel	$40,735.73	$245,263.77
Coldbrook-Swift Tunnel	13,617.89	46,542.60
Swift River Reservoir	78,044.01	363,724.78
Main Dam and Dike	19,751.47	19,751.47
Southern Sudbury Emergency Supply	10.94	33,407.97
Total Engineering, Headquarters Office	$152,160.04	$708,690.59
Wachusett-Coldbrook Tunnel		
General Overhead:		
Administration	$9,454.57	$59,413.86
Engineering	40,735.73	245,263.77
Total General Overhead	$50,190.30	$304,677.63
Engineering:		
Salaries, Engineering and Clerical	$68,297.22	$373,046.20
Consultant Expense	2,829.35	7,183.97
Labor	494.00	494.00
Furniture and Fixtures	16.66	1,681.02
Engineering Instruments	–347.93	7,694.67
Rent and Upkeep	2,327.67	10,600.19
Automobile Purchase	50.00	8,493.47
Automobile Maintenance	2,494.11	12,511.74
Contracts for Investigations and Surveys	2,565.58	18,640.69
Miscellaneous Expense (undistributed)	1,027.25	7,172.63
Advertising	0.00	6.05
Printing and Blueprinting	68.24	791.43
Stationery and Office Supplies	276.91	2,202.45
Postage	31.97	276.82
Total Engineering	$80,131.03	$450,795.33
Real Estate, *General Construction:*		
Legal and Expert Expense	$655.51	$4,832.92
Consultant Expense	0.00	394.40
Labor	0.00	906.55
Miscellaneous Expense	3.40	286.45
Purchases and Settlements	0.00	115,089.71
Taxes	539.99	2,577.97
Maintenance of Real Estate	206.55	518.14
Police Protection, Labor	5.00	25.00
Fire Protection	0.00	30.97
Special Agents, Salaries	2,430.00	8,193.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	0.00	903.50
Automobile Maintenance	319.31	1,501.97
Miscellaneous Expense (undistributed)	178.36	817.33
Printing	0.00	7.89
Postage	6.00	10.36
Total Real Estate	$4,344.12	$136,213.83

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
WARE WATERSHED PROTECTION:		
Salaries, Engineering and Clerical	$20,600.99	$33,553.97
Legal and Expert Expense	2,061.51	8,498.06
Consultant Expense	0.00	763.70
Labor	2,913.33	6,350.88
Contracts	3,090.51	4,395.51
Miscellaneous Expense (undistributed)	943.39	1,266.03
Printing and Blueprinting	88.13	255.00
Installed Equipment	2,043.90	2,043.90
Purchases and Settlements	46,253.69	519,808.84
Taxes	5,149.03	11,007.33
Maintenance of Real Estate	132.81	132.81
Automobile Maintenance	21.63	21.63
Total Ware Watershed Protection	$83,298.92	$588,097.66
WARE DIVERSION DAMAGES:		
Salaries, Engineering and Clerical	$15,346.28	$35,749.34
Legal and Expert Expense	822.96	832.24
Consultant Expense	563.26	2,989.65
Labor	2,000.31	2,033.33
Laboratory Equipment	43.90	102.47
Laboratory Supplies	0.00	27.88
Engineering Instruments	421.52	466.60
Rental of Equipment	99.00	177.25
Automobile Maintenance	70.52	70.52
Contracts for Investigations and Surveys	0.00	63.27
Materials of Construction	136.51	136.51
Miscellaneous Expense (undistributed)	1,297.49	4,567.78
Printing and Blueprinting	50.10	125.64
Postage	5.00	5.75
Purchases and Settlements	22,500.00	22,500.00
Total Ware Diversion Damages	$43,356.85	$69,848.23
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 4, Sinking Shaft 5 and driving 1,367 linear feet of tunnel	$0.00	$290,581.99
Contract No. 8, Sinking Shafts 6 and 7 and driving 3,062.2 linear feet of tunnel	0.00	456,784.26
Contract No. 10, Construction and maintenance of Transmission Line	8,630.16	119,547.39
Contract No. 12, Sinking Shafts 2, 3 and 4 and driving 3,809.6 linear feet of tunnel	0.00	632,727.44
Contract No. 14, Construction of East Portion of Wachusett-Coldbrook Tunnel and Shaft 1	472,619.80	3,505,787.06
Contract No. 17, Construction of West Portion of Wachusett-Coldbrook Tunnel and Shaft 8	193,439.52	4,127,094.19
Contract No. 18, Furnishing Iron Castings for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	0.00	19,431.07
Contract No. 19, Construction of Dam, and Substructure of Intake Building for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	58,169.20	285,580.49
Contract No. 22, Furnishing and Installing an Unwatering Pump in Shaft 1 of the Wachusett-Coldbrook Tunnel	11,334.43	11,334.43

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Contract No. 24, Construction of Superstructure of Intake Building for the Ware River Intake Works of the Wachusett-Coldbrook Tunnel	$55,295.36	$62,850.96
Contract No. 25, Construction of Superstructure of Outlet Building for the Wachusett-Coldbrook Tunnel	40,271.91	54,280.93
Contract No. 26, Furnishing and Installing Power and Lighting Wiring and Electrical Equipment at the Outlet Works at Shaft 1 of the Wachusett-Coldbrook Tunnel	8,899.76	8,899.76
Contract No. 28, Grading the Grounds at the Ware River Intake Building of the Wachusett-Coldbrook Tunnel	4,538.43	4,538.43
Contract No. 29, Grading the Grounds at the Outlet Building of the Wachusett-Coldbrook Tunnel	8,458.87	8,458.87
Contract No. 31, Construction of the Superstructure of the Head House at Shaft 4 of the Wachusett-Coldbrook Tunnel	2,447.55	2,447.55
Total Contracts	$864,104.99	$9,590,344.82
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$11,707.29	$59,565.90
Temporary Equipment	0.00	5,013.60
Labor	1,094.75	1,094.75
Miscellaneous Expense	1,985.84	9,238.38
Contracts for Investigations and Surveys	0.00	898.34
Maintenance of Partially Completed Structures	2,905.98	2,905.98
Rental of Equipment	7.00	7.00
Total	$17,700.86	$78,723.95
Total Wachusett-Coldbrook Tunnel	$1,143,127.07	$11,218,701.45
SPECIAL INVESTIGATION — POLLUTION OF WARE AND QUINAPOXET WATERSHEDS. (Expenditures under Chapter 66, Acts of 1931.)		
Salaries, Engineering	$986.67	$986.67
Miscellaneous Expense	1,009.32	1,009.32
Total Special Investigation	$1,995.99	$1,995.99
COLDBROOK-SWIFT TUNNEL		
GENERAL OVERHEAD:		
Administration	$3,517.23	$10,870.73
Engineering	13,617.89	46,542.60
Total General Overhead	$17,135.12	$57,413.33
ENGINEERING:		
Salaries, Engineering and Clerical	$22,571.37	$58,812.62
Labor	72.25	72.25
Furniture and Fixtures	101.43	651.34
Engineering Instruments	496.91	3,970.71
Rent and Upkeep	1,305.06	5,163.50
Automobile Purchase	1,880.22	6,442.97
Automobile Maintenance	2,641.48	10,436.37
Contracts for Investigations and Surveys	694.01	13,525.66

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Materials of Construction	$0.00	$2.25
Miscellaneous Expense (undistributed)	1,975.43	4,978.65
Printing and Blueprinting	163.40	433.47
Stationery and Office Supplies	330.54	1,374.35
Postage	38.00	220.30
Total Engineering	$32,270.10	$106,084.44
REAL ESTATE:		
Legal and Expert Expense	$988.64	$2,774.28
Labor	9.00	9.00
Miscellaneous Expense (undistributed)	7.46	27.16
Printing and Blueprinting	20.92	34.73
Postage	5.68	5.68
Purchases and Settlements	11,565.00	13,415.00
Taxes	0.00	22.50
Maintenance of Real Estate	9.25	9.25
Fire Protection Equipment	26.83	60.86
Total Real Estate	$12,632.78	$16,358.46
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 20, Construction of Coldbrook-Swift Tunnel	$303,157.22	$303,157.22
Total Contracts	$303,157.22	$303,157.22
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$64.75	$64.75
Installed Equipment	0.00	91.87
Miscellaneous Expense	93.38	93.38
Total	$158.13	$250.00
Total Coldbrook-Swift Tunnel	$365,353.35	$483,263.45
SWIFT RIVER RESERVOIR		
GENERAL OVERHEAD:		
Administration	$10,516.22	$59,229.49
Engineering	78,044.01	363,724.78
Total General Overhead	$88,560.23	$422,954.27
ENGINEERING:		
Salaries, Engineering and Clerical	$24,572.04[1]	$260,933.58
Labor	904.65[1]	3,083.59
Furniture and Fixtures	167.44	2,863.48
Laboratory Equipment	–47.64[1]	210.70
Rental of Equipment	0.00	0.50
Engineering Instruments	259.88	5,696.27
Rent and Upkeep	799.39	3,063.67
Automobile Purchase	1,536.65	12,106.10
Automobile Maintenance	1,472.99	10,463.78
Special Experiments	0.00	392.40
Contracts for Investigations and Surveys	–33,253.85[1]	11,592.48
Office Buildings	0.00	4,835.91
Miscellaneous Expense (undistributed)	155.20[1]	3,258.19
Printing and Blueprinting	94.34	953.44
Stationery and Office Supplies	317.30	3,396.24
Postage	65.50	387.00
Total Engineering	–$2,956.11[1]	$323,237.33

[1] Expenditures previously carried in these accounts but chargeable in their entirety to the Main Dam and Dike have been transferred to accounts opened this year under that heading.

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
REAL ESTATE:		
Legal and Expert Expense	$14,243.70	$108,019.53
Labor	0.00	67.35
Furniture and Fixtures	0.00	15.68
Miscellaneous Expense (undistributed)	530.68	2,872.99
Advertising	0.00	208.66
Printing and Blueprinting	197.53	555.18
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	662,810.47	4,682,507.16
Taxes	31,404.91	88,030.70
Maintenance of Real Estate	142.92	749.34
Fire Protection Equipment	614.53	3,338.97
Automobile Purchase	571.69	771.69
Automobile Maintenance	66.96	219.05
Miscellaneous Expense	10.47	75.99
Police Protection Labor	5.00	10.00
Special Agents, Salaries	2,430.00	8,541.33
Equipment	0.00	118.33
Automobile Purchase	0.00	917.96
Automobile Maintenance	412.03	1,662.17
Miscellaneous Expense (undistributed)	149.20	633.84
Printing and Blueprinting	0.00	41.60
Stationery and Office Supplies	3.27	6.79
Postage	3.00	7.42
Renting Agents, Salaries	2,760.00	10,015.43
Furniture and Fixtures	0.00	29.29
Stationery and Office Supplies	4.79	8.79
Miscellaneous Expense	91.26	299.22
Payments to Towns	2,000.00	6,000.00
Total Real Estate	$718,452.41	$4,915,724.91
SWIFT RESERVOIR DAMAGES:		
Salaries, Engineering	$34.10	$48.68
Consultant Expense	0.00	1,443.37
Purchases and Settlements	33.00	14,140.00
Miscellaneous Expense	0.00	2.70
Total Swift Reservoir Damages	$67.10	$15,634.75
SWIFT DIVERSION DAMAGES:		
Salaries, Engineering	$10,053.87	$24,449.07
Legal and Expert Expense	1,152.00	1,152.00
Consultant Expense	1,369.61	6,418.57
Labor	44.90	44.90
Laboratory Equipment	363.52	537.96
Laboratory Supplies	0.00	20.98
Rental of Equipment	0.00	9.00
Engineering Instruments	5.68	561.03
Automobile Maintenance	42.37	43.62
Contracts for Investigations and Surveys	0.00	569.47
Materials of Construction	18.99	18.99
Miscellaneous Expense (undistributed)	1,376.70	4,267.62
Printing and Blueprinting	53.97	117.26
Purchases and Settlements	202,500.00	202,500.00
Total Swift Diversion Damages	$216,981.61	$240,710.47
CEMETERIES:		
Salaries, Engineering and Clerical	$2,208.15	$4,984.96
Legal and Expert Expense	25.25	68.75

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Labor	$1,301.12	$4,867.76
Automobile Purchase	3,830.00	3,830.00
Automobile Maintenance	206.83	206.83
Miscellaneous Expense (undistributed)	5.32	86.21
Stationery and Office Supplies	0.00	3.51
Contract 34	2,370.53	2,370.53
Purchases and Settlements	1,091.10	4,643.10
Monuments and Inscriptions	7.70	252.25
Materials	994.49	2,520.05
Transportation of Bodies	0.00	45.00
Transportation of Monuments	62.50	840.50
Rental of Equipment	10.00	10.00
Total Cemeteries	$12,112.99	$24,729.45
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$214.78
Total	$0.00	$214.78
HIGHWAY AND PUBLIC UTILITY RELOCATION:		
Salaries, Engineering and Clerical	$6,012.25	$6,012.25
Legal and Expert Expense	40.10	40.10
Labor	88.50	88.50
Automobile Maintenance	39.75	39.75
Miscellaneous Expense (undistributed)	33.49	33.49
Printing and Blueprinting	16.68	16.68
Contract 21	48,180.41	48,180.41
Total Highway and Public Utility Relocation	$54,411.18	$54,411.18
Total Swift River Reservoir	$1,087,629.41	$5,997,617.14
SWIFT RIVER RESERVOIR — MAIN DAM AND DIKE		
GENERAL OVERHEAD:		
Administration	$5,097.35	$5,097.35
Engineering	19,751.47	19,751.47
Total General Overhead	$24,848.82	$24,848.82
ENGINEERING:		
Salaries, Engineering and Clerical	$24,702.87[1]	$24,702.87
Consultant Expense	1,312.55	1,312.55
Labor	168.10[1]	168.10
Furniture and Fixtures	64.18	64.18
Laboratory Equipment	566.20[1]	566.20
Automobile Maintenance	47.28	47.28
Contracts for Investigations and Surveys	38,772.51[1]	38,772.51
Miscellaneous Expense (undistributed)	820.20[1]	820.20
Stationery and Office Supplies	64.78	64.78
Total Engineering	$66,518.67	$66,518.67
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 30, Constructing Stream Control Works at Main Dam of Swift River Reservoir	$59,361.75	$59,361.75
Contract No. 32, Constructing Exploratory Caissons at Main Dam and Dike of Swift River Reservoir	11,247.75	11,247.75
Total Contracts	$70,609.50	$70,609.50

[1]Includes expenditures prior to November 30, 1930, previously carried in other accounts.

PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Miscellaneous Expense	$3.00	$3.00
Total	$3.00	$3.00
Total Swift River Reservoir — Main Dam and Dike	$161,979.99	$161,979.99

SOUTHERN SUDBURY EMERGENCY SUPPLY

GENERAL OVERHEAD:		
Administration	$22.52	$8,690.28
Engineering	10.94	33,407.97
Total General Overhead	$33.46	$42,098.25
ENGINEERING:		
Salaries	$0.00	$33,810.46
Consultant Expense	0.00	3,816.25
Furniture and Fixtures	0.00	30.70
Engineering Instruments	0.00	216.06
Rent and Upkeep	0.00	543.40
Automobile Purchase	0.00	1,719.00
Automobile Maintenance	0.00	1,514.45
Labor	0.00	173.00
Miscellaneous Expense (undistributed)	0.00	1,575.75
Printing and Blueprinting	0.00	215.33
Stationery and Office Supplies	0.00	567.87
Postage	0.00	52.80
Total Engineering	0.00	$44,235.07
REAL ESTATE:		
Legal and Expert Expense	$39.01	$2,213.82
Consultant Expense	0.00	116.87
Printing and Blueprinting	0.97	4.28
Purchases and Settlements	125.00	27,763.22
Taxes	131.70	253.79
Total Real Estate	$296.68	$30,351.98
SOUTHERN SUDBURY DIVERSION DAMAGES:		
Consultant Expense	$0.00	$990.00
Legal and Expert Expense	0.00	212.66
Settlements	0.00	49,550.00
Total Southern Sudbury Diversion Damages	$0.00	$50,752.66
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 5, Cordaville Pipe Line	$0.00	$83,262.86
Contract No. 6, Cordaville Pumping Station	0.00	17,385.04
Contract No. 7, Hopkinton Pipe Line	0.00	134,365.72
Contract No. 11, Ashland Pipe Line	0.00	130,145.35
Contract No. 13, Whitehall Pipe Line	0.00	60,603.17
Contract No. 16, Whitehall Open Channel	0.00	32,695.16
Total Contracts	$0.00	$458,457.30

	Year ending Nov. 30, 1931	Total to Nov. 30, 1931
Permanent Construction — Except Construction Contracts:		
Installed Equipment	$0.00	$7,960.51
Miscellaneous Expense	0.00	2,758.77
Labor	0.00	1,011.00
Materials of Construction	0.00	207.09
Total	$0.00	$11,937.37
Total Southern Sudbury Emergency Supply	$330.14	$637,832.63

Summary

Wachusett-Coldbrook Tunnel	$1,143,127.07	$11,218,701.45
Special Investigation — Pollution of Ware and Quinapoxet Watersheds	1,995.99	1,995.99
Coldbrook-Swift Tunnel	365,353.35	483,263.45
Swift River Reservoir	1,087,629.41	5,997,617.14
Main Dam and Dike	161,979.99	161,979.99
Southern Sudbury Emergency Supply	330.14	637,832.63
Unassigned	–1.73	643.51
Grand Total	$2,760,414.22	$18,502,034.16

Receipts from Rents, Sales, Etc.

Receipts from Sales	$40,110.11	$90,264.33
Receipts from Rents	49,432.26	153,113.78
Miscellaneous Receipts	1,825.24	2,352.14
Total Receipts	$91,367.61	$245,730.25

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE SWIFT RIVER RESERVOIR

(TITLE VESTED IN COMMONWEALTH)

TOWNS	TOTAL – NOV. 30, 1930. 1930 ANNUAL REPORT (ACRES)	TOTAL – NOV. 30, 1930. REVISED - SEE NOTE (ACRES)*	TOTAL FOR YEAR ENDING NOV. 30, 1931 (ACRES)	TOTAL NOV. 30, 1931. (ACRES)	REMARKS
BELCHERTOWN	1,687	1,653	0	1,653	
DANA	5,481	5,477	1,394	6,871	* Revisions have been made using acreages obtained from surveys wherever available, otherwise from deeds, property blanks etc.
ENFIELD	6,378	6,239	171	6,410	
GREENWICH	7,924	7,536	865	8,401	
HARDWICK	2,786	2,147	77	2,224	
NEW SALEM	5,039	5,239	186	5,425	
PELHAM	1,891	1,834	261	2,095	
PETERSHAM	420	517	444	961	
PRESCOTT	7,958	7,783	836	8,619	
SHUTESBURY	781	863	627	1,490	
WARE	280	202	224	426	
WENDELL	37	37	0	37	
TOTALS	40,662	39,527	5,085	44,612	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TAKINGS OF REAL ESTATE (AND WATER RIGHTS)

TAKING FOR	TAKING NO.	TOWN	COUNTY	PLAN NO.	DATE OF TAKING	TITLE VESTED IN COMMONWEALTH FEE (Acres)	EASEMENT (Acres)
Southern Sudbury Emergency Supply.	1 to 9 inc	Details previously reported in 1930.		C-1 to C-15 incl.	July 8, 1927 to Sept. 23, 1930.	258.81 (Also Water Rights)	29.02
Wachusett-Coldbrook Tunnel.	1 to 4 inc	Details previously reported in 1930.		T-1 to T-13 incl.	July 22, 1927 to Aug. 21, 1928.	570.22	20.37
Coldbrook-Swift Tunnel.	1	Details previously reported in 1930.		T-14	Sept. 24, 1929.		3.53
" " "	2	Barre	Worcester	T-14A to T-26 inc.	Mar. 13, 1931.	40.51	
		Hardwick				408.87	0.53
" " "	3	Hardwick	Worcester	T-27	Mar. 13, 1931.	27.73	
		Greenwich	Hampshire			67.70	
		*(391.42 acres of this total are within the Swift River Res. Area)				* 544.81	4.06
Swift River Reservoir, - Cemetery.	1	Ware	Hampshire	S-1	June 5, 1931.	** 79.81	
" " "	2	Belchertown	Hampshire	S-7	July 14, 1931.	72.21	
" " " - Highway.	3	Belchertown	Hampshire	S-2 to S-6 inc.	July 17, 1931.	30.55	0.26
		Ware				23.27	0.13
		**(Orig. area was 82.22 acres.-2.41 acres included in Taking No. 3)				205.84	0.39
Ware River Watershed,-School.	1	Oakham	Worcester	W-1	Sept. 1, 1931.	0.25	
" " . Taking of Flood Waters of the Ware River and its Tributaries above Diversion Dam at Coldbrook in Barre.		Barre	Worcester	No Plan	Mar. 6, 1931.	Water Rights.	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED PRIOR TO NOV. 30, 1930

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
1	Borings	Tunnel Line	Ware & Swift	Pennsylvania Drilling Company	Nov. 5, 1926	Nov. 9, 1926	8,260.00	18,641.69	July 15, 1927
2	Borings	Swift Dam & Dike Sites	Swift	Sprague & Henwood, Incorporated	Nov. 5, 1926	Nov. 9, 1926	9,730.00	26,885.83	June 3, 1927
3	Aerial Photographs	Swift River Valley	Swift	Fairchild Aerial Surveys, Incorporated		Nov. 12, 1926	6,955.00	5,997.50	Nov. 2, 1927
4	Shaft 5	Rutland	Ware	James J. Coughlan & Sons, Incorporated	Mar. 25, 1927	Mar. 28, 1927	137,854.80	290,581.99*	June 12, 1928
5	Cordaville Pipe Line	Cordaville to Sudbury Res.	So. Sudbury	Lock Joint Pipe Co.	Apr. 15, 1927	Apr. 15, 1927	78,818.00	83,762.86	Jan. 9, 1928
6	Cordaville Pumping Station	Cordaville	So. Sudbury	F.A. Mazzur Co., Inc.	Apr. 29, 1927	May 2, 1927	16,357.00	17,385.04	May 16, 1928
7	Hopkinton Pipe Line	Hopkinton Res. to Cordaville.	So. Sudbury	Cenedella & Co.	Apr. 29, 1927	May 4, 1927	126,550.00	134,365.72	Dec. 27, 1927
8	Shafts 6 & 7	Rutland	Ware	James J. Coughlan & Sons, Incorporated	May 20, 1927	May 24, 1927	162,125.00	456,784.26*	June 12, 1928
9	Aerial Photographs	Chicopee and Ware Rivers	Ware	Fairchild Aerial Surveys, Incorporated		Mar. 30, 1927	3,090.00	2,560.00	Feb. 17, 1928
11	Ashland Pipe Line	Ashland Res. to Res. No. 2, Gate Ho.	So. Sudbury	Antonio Magavero	June 3, 1927	June 3, 1927	125,150.00	130,145.35	Sept. 24, 1928
12	Shafts 2, 3 & 4	Holden & Rutland	Ware	Dravo Contracting Company	May 20, 1927	May 24, 1927	259,800.00	632,727.44*	June 12, 1928
13	Whitehall Pipe Line	Whitehall Res. to City Road	So. Sudbury	Portland Contracting Company, Incorporated	July 15, 1927	July 15, 1927	54,963.00	60,603.17	June 12, 1928
15	Electric Power	Cordaville Pumping Station	So. Sudbury	Marlborough Electric Company		Aug. 4, 1927		** 270.09	June 1, 1928
16	Whitehall Open Channel	City Road to Hopkinton Res.	So. Sudbury	Sanders Engineering Company	Sept. 23, 1927	Sept. 23, 1927	36,720.00	32,695.16	July 9, 1928
18	Iron Castings for Ware River Intake Works	Barre	Ware	Barbour Stockwell Co.	Jan. 4, 1929	Jan. 8, 1929	18,697.83	19,431.07	Jan. 11, 1930

* This amount includes construction beyond that which was contemplated when proposal was made.
** The Metropolitan District Commission has paid all bills for this contract subsequent to June 1, 1928.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS IN PROGRESS BETW'N NOV. 30. 1930 & NOV. 30. 1931

SHEET 1 OF 2 SHEETS

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	DATE AWARDED (DATE OF FINAL EST.)	BASIS OF AWARD	PAYMENTS TO DATE
10.	Transmission Line for Construction of Wachusett-Coldbrook Tunnel.	Tunnel Line	Ware	New England Power Company			April 27, 1927 (June 10, 1931)	Maint. at Cost. Constr. at Cost.	*$ 33,107.81 * 86,439.58
14.	East Portion of Wachusett-Coldbrook Tunnel.	West Boylston, Holden and Rutland.	Ware	West Construction Co. Assignee	Nov. 18, 1927	13	April 30, 1928 (July 28, 1931)	$ 4,074,981.25 **	+ 3,505,787.06
17.	West Portion of Wachusett-Coldbrook Tunnel.	Rutland, Oakham and Barre.	Ware	West Construction Co. Assignee	Nov. 18, 1927	12	April 30, 1928 (May 15, 1931)	4,799,362.50 ***	* 4,127,094.19
19.	Dam and Substructure of Intake Building.	Barre	Ware	J. W. Bishop Co.	July 16, 1929	7	July 23, 1929 (Mar. 9, 1931)	273,077.00	*285,580.49
20.	Coldbrook-Swift Tunnel.	Barre, Hardwick and Greenwich.	Swift	Wenzel & Henoch, Construction Co.	Mar. 27, 1931	13	April 10, 1931	4,978,031.80	303,157.22
21.	Portion of the Ware Belchertown Highway	Ware and Belchertown.	Swift	The Lane Construction Company	July 17, 1931	17	July 17, 1931	208,381.50	48,180.41
22.	Unwatering Pump at Shaft 1.	West Boylston.	Ware	F. A. Mazzur Co., Inc.	Nov. 5, 1929	3	Nov. 12, 1929	11,975.00	11,334.43
23.	Making Borings.	Belchertown, Ware, Enfield, Greenwich & Hardwick	Swift	Sprague & Henwood Inc.	Nov. 5, 1929	6	Nov. 5, 1929	10,950.00	17,481.66
24.	Superstructure of Ware River Intake Building	Barre	Ware	Munroe & Wescott Inc.	July 22, 1930	10	July 22, 1930	69,669.00	62,850.96

Awarded to lowest bidder in each case.

* Final Estimate. + Final Estimate = $3,515,787.08

** Portion of work completed under Contract 12 before Contract 14 was executed reduces this amount by about 7%.

*** Portion of work completed under Contracts 4 & 8 before Contract 17 was executed reduces this amount by about 7%.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS IN PROGRESS BETW'N NOV. 30, 1930 & NOV. 30, 1931

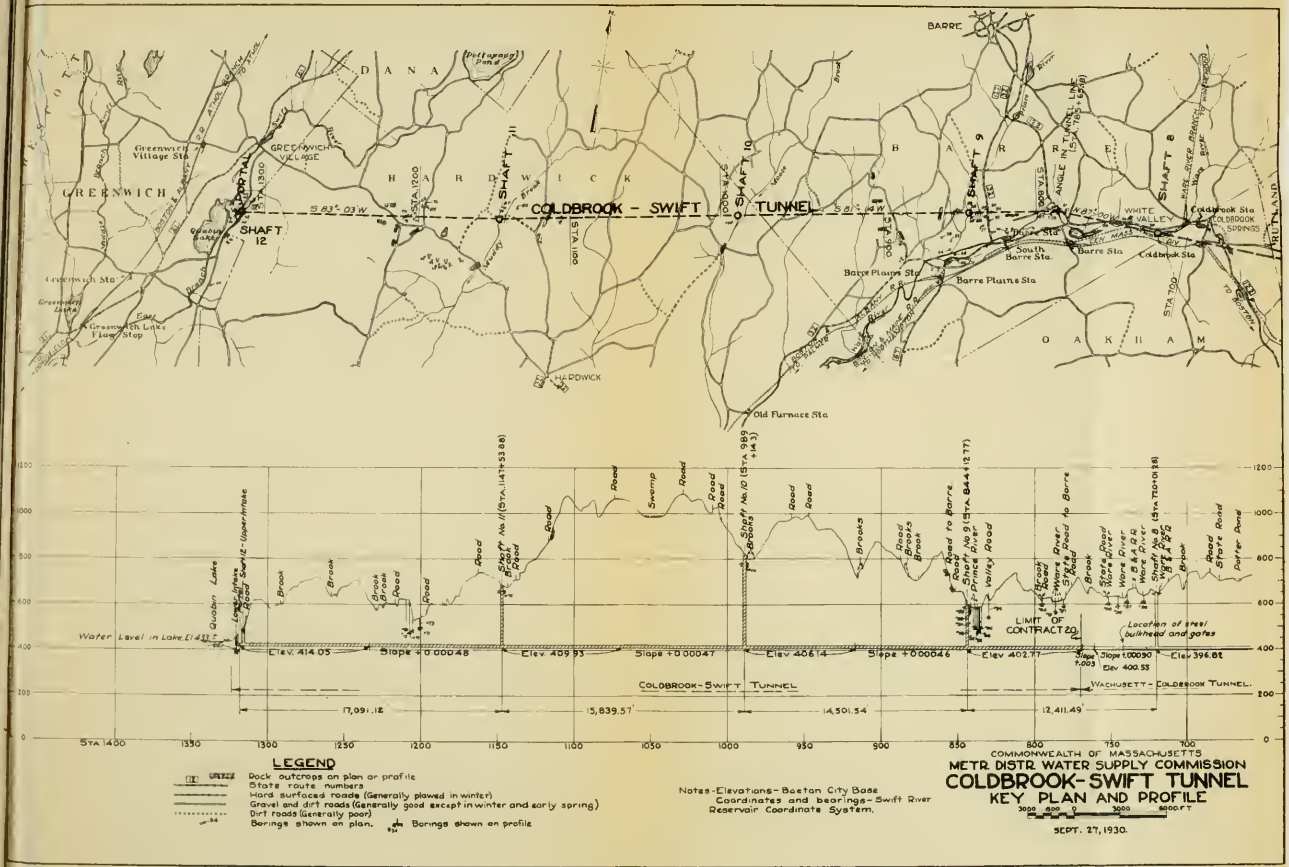
SHEET 2 OF 2 SHEETS

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	DATE AWARDED (DATE OF FINAL EST)	BASIS OF AWARD	PAYMENTS TO DATE
25.	Superstructure of Outlet Works at Shaft 1.	West Boylston	Ware	Munroe & Wescott Inc.	July 22, 1930	10	July 22, 1930	$61,363.00	$54,280.93
26.	Wiring and Electrical Equipment Outlet Works Shaft 1.	West Boylston	Ware	Anderson-Coffey Co. Inc.	Sept. 23, 1930	8	Sept. 23, 1930	8,850.00	8,899.76
27.	Earth Fill along Ware River.	Barre	Ware	Raymond A. Bergesson	Sept. 23, 1930	14	Sept. 23, 1930 (Dec. 20, 1930)	4,050.00	* 4,395.51
28.	Grading Grounds of Ware River Intake Building.	Barre	Ware	Anthony Ross & Son	Aug. 14, 1931	16	Aug. 14, 1931	6,571.75	4,538.43
29.	Grading Grounds of Wachuseth Outlet Building.	West Boylston	Ware	Anthony Ross & Son	Aug. 14, 1931	17	Aug. 14, 1931	9,998.05	8,458.87
30.	Stream Control Works at Main Dam of Swift River Reservoir.	Bekhertown, Enfield and Ware	Swift	Northern States Contracting Co.	July 17, 1931	19	July 21, 1931.	560,922.50	59,361.75
31.	Head House at Shaft 4.	Rutland	Ware	E. D. Ward Co.	Aug. 25. 1931	8	Aug. 25, 1931	5,439.00	2,447.55
32.	Exploratory Caissons at Main Dam and Dike of Swift River Reservoir.	Enfield and Ware	Swift	Dravo Contracting Co.	Sept. 8, 1931	10	Sept. 8, 1931	** (A) 115,900.00 (B) 133,825.00	11,247.75
33.	Purchase of Power at Shaft 1.	West Boylston	Ware	New England Power Co.	Date of Agreement =		Aug. 6, 1931.	Agreed Rates	1,154.05
34.	Driveways in New Cemetery Developement.	Ware	Swift	The Lane Construction Company.	Oct. 20, 1931	16	Oct. 27, 1931.	4,967.50	2,370.53

Awarded to lowest bidder in each case.

* Final Estimate.

** (A) Assuming caissons to be sunk mostly by open dredging.
(B) " " " " " " under pressure



COLDBROOK - SWIFT TUNNEL
GREENWICH
HARDWICK
BARRE
OAKHAM
RUTLAND
DANA
Greenwich Village Sta
GREENWICH VILLAGE
PORTAL
SHAFT 12
SHAFT 11
SHAFT 10
SHAFT 9
SHAFT 8
ANGLE IN TUNNEL LINE (STA. 785+65.8)
WHITE VALLEY
Coldbrook Sta
COLDBROOK SPRINGS
South Barre Sta.
Barre Sta
Barre Plains Sta
Old Furnace Sta
HARDWICK
Greenwich Sta
Greenwich Lake Flag Stop
Quabin Lake
Water Level in Lake, El 433.2
Elev. 414.05
Slope +0.00048
Elev. 409.93
Slope +0.00047
Elev. 406.14
Slope +0.00046
Elev. 402.77
Slope +.003
Slope +.00030
Elev. 400.53
Elev. 396.82
LIMIT OF CONTRACT 20
Location of steel bulkhead and gates
COLDBROOK-SWIFT TUNNEL
WACHUSETT-COLDBROOK TUNNEL
17,091.12
15,839.57
14,501.54
12,411.49
STA 1400
1350
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
LEGEND
Rock outcrops on plan or profile
State route numbers
Hard surfaced roads (Generally plowed in winter)
Gravel and dirt roads (Generally good except in winter and early spring)
Dirt roads (Generally poor)
Borings shown on plan.
Borings shown on profile
Notes-Elevations-Boston City Base
Coordinates and bearings-Swift River Reservoir Coordinate System.
COMMONWEALTH OF MASSACHUSETTS
METR DISTR WATER SUPPLY COMMISSION
COLDBROOK-SWIFT TUNNEL
KEY PLAN AND PROFILE
SEPT. 27, 1930.

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of the year 1926, respectfully presents for the year ending November 30, 1932, its

SEVENTH ANNUAL REPORT

I. Organization and Administration

Davis B. Keniston continued during the year as Chairman of the Commission, and Charles M. Davenport and Thomas D. Lavelle, both of Boston, as Associate Commissioners. R. Nelson Molt continued as Secretary.

The clerical force of the Commission's office at Boston remained the same throughout the year, and three special agents under the direction of the Commission, continued to care for property acquired by the Commission in the Swift River and Ware River areas. Real estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 131 employees during the year. The maximum number employed at any one time by contractors on the various construction projects during the year was 541 persons.

II. Engineering Department

Frank E. Winsor continued as Chief Engineer, Karl R. Kennison as Designing Engineer, and Walton H. Sears as Mechanical Engineer.

The field divisions were continued in charge of three division engineers as follows: Wachusett-Coldbrook Tunnel Division, William W. Peabody; Coldbrook-Swift Tunnel Division, Richard R. Bradbury; Swift River Reservoir Division, N. LeRoy Hammond.

The Commission retained the services of J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, and the services of X. H. Goodnough, Inc., as consulting engineers. Charles T. Main of Boston was employed from time to time as a general consultant on mill and water power damages and also on the design of the dam and dike of Quabbin Reservoir. Dr. Charles P. Berkey of Columbia University continued as consulting geologist. Other consultants were employed from time to time as needed.

III. Offices

The office of the Commission and of the Chief Engineer continued on the ninth floor of the Metropolitan District Commission Building at 20 Somerset Street, Boston. The division offices for the Quabbin Aqueduct, heretofore referred to as the Wachusett-Coldbrook Tunnel and the Coldbrook-Swift Tunnel, and the Quabbin Reservoir, heretofore referred to as the Swift River Reservoir, were continued at Holden, Hardwick and Enfield respectively. The laboratories for water analysis and soil testing were continued at Enfield.

IV. Real Estate

The Commission, for reservoir purposes, has concluded the purchase of (or has under option) a total of 49,756 acres of land in the Swift River watershed, and for sanitary protection and construction purposes in the Ware River watershed a total of 4,067 acres.

The Commission acquired by eminent domain 226.06 acres of land in the towns of Ware and Enfield and Greenwich for construction purposes for the main dam and dike of Quabbin Reservoir in the Swift River valley.

The Commission, acting under the provisions of Section 4 of Chapter 321 of the Acts of 1927, has negotiated settlement with the Thorndike Company of Boston, Massachusetts, of all damages for the present and future diversions of the waters of the Ware and Swift Rivers.

The Commission continued, through duly appointed agents, the direction of the town government of the Town of Prescott as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

V. Reservoirs and Aqueducts

The Commission on October 25 gave the name Quabbin Reservoir to the reservoir to be constructed in the Swift River valley and previously referred to as the Swift River Reservoir.

The Commission also gave the name Quabbin Aqueduct to the tunnel which will connect Quabbin Reservoir and Wachusett Reservoir, consisting of the Wachusett-Coldbrook Tunnel already constructed and in operation for diverting the flood flows of the Ware River at Coldbrook into Wachusett Reservoir, and its extension, the Coldbrook-Swift Tunnel, now under construction from Coldbrook to Greenwich.

VI. Cemeteries

The Commission on May 18 gave the name Quabbin Park Cemetery to the new cemetery established by the Commission in the Town of Ware at the easterly end of the relocated portion of the state highway between Ware and Belchertown. On August 25 the Commission notified and requested officials in charge of the following cemeteries that no further interments should be permitted in these cemeteries, replaced by the new Quabbin Park Cemetery:

Town	*Cemetery*
Belchertown	Blue Meadow
Dana	Pine Grove, Towne
Enfield	Woodlawn, Church, Cemetery Hill
Greenwich	Greenwich
Prescott	Fish Hill, Pelham Hollow, Pine Grove, Town House, Jason Powers
Shutesbury	Hamilton

Parties interested in the removal of bodies were given the privilege of selecting lots in Quabbin Park Cemetery. The Commission has provided for the sale of lots in Quabbin Park Cemetery to any person who may have had an interest in the cemeteries from which bodies are to be removed.

The Commission has constructed a receiving tomb at the entrance of Quabbin Park Cemetery and the cemetery site has been cleared and landscaped and driveways completed throughout.

In consequence of requests from relatives of deceased persons, 233 bodies have been removed from the Quabbin Reservoir area during the year and of this number 62 have been interred in Quabbin Park Cemetery since August 25, when lots in this cemetery were first available. A total of 760 bodies have been removed from the Quabbin Reservoir area.

VII. Ware River Supply

The Commission, in accordance with the provisions of Chapter 375 of the Acts of 1926, during the period between December 23, 1931, and October 22, 1932, diverted down Shaft 8 through the Quabbin Aqueduct, previously referred to as the Wachusett-Coldbrook tunnel, into Wachusett Reservoir, 9,735,200,000 gallons of water.

Work was completed by Munroe & Westcott, Inc., under two contracts, numbered 24 and 25, for the construction respectively of the superstructure of the intake building for the Ware River intake works at Shaft 8, and of the superstructure of the outlet works at Shaft 1, and by Anderson-Coffey Company, Inc., under contract No. 26 for electrical work in the latter building.

Two contracts, numbered 28 and 29, awarded to Anthony Ross & Son, in August, 1931, for grading the grounds, respectively, of the Ware River intake building in the Town of Barre, and of the Wachusett outlet building in the Town of West Boylston were completed.

Contract No. 31, awarded in August, 1931, to E. D. Ward Company, for constructing the superstructure of the head house at Shaft 4 of the Quabbin Aqueduct in the Town of Rutland, was completed.

VIII. Swift River Supply

Real estate and topographic surveys were continued during the year.

The Wenzel & Henoch Construction Company, who in April, 1931, was awarded a contract, numbered 20, for the 10.4 miles of Quabbin Aqueduct to be constructed in the towns of Barre, Hardwick and Greenwich between the Ware River intake works at Coldbrook and Quabbin Reservoir, continued their work. About 70% of the rock excavation to be removed under this contract has been completed.

Contract No. 21, awarded in July, 1931, to The Lane Construction Corporation, for the construction of a substitute highway in the Towns of Ware and Belchertown, was completed and the highway was turned over to the Department of Public Works on September 7 and on September 22 opened to traffic as a state highway. This highway, about 5.26 miles in length, is a substitute for that portion of the Ware-Belchertown road passing through the Quabbin Reservoir area in the towns of Ware, Enfield and Belchertown and is a portion of state highway designated 109.

Contract No. 30, awarded in July, 1931, to the Northern States Contracting Company, for constructing the stream control works preliminary to the building of the main dam of Quabbin Reservoir in the Swift River valley, was nearly completed.

Contract No. 32, awarded in September, 1931, to The Dravo Contracting Company, for constructing exploratory caissons at the proposed sites of the main dam and dike of the Quabbin Reservoir in the Town of Enfield and in the Town of Ware, to disclose the character of subsurface material and conditions for the determination of the type and design of those structures, has been completed.

Contract No. 34, awarded in October, 1931, to The Lane Construction Corporation, for the construction of an entrance and driveways in Quabbin Park Cemetery in the Town of Ware, has been completed.

The Commission on November 8 authorized the advertisement for sealed proposals to be publicly opened and read on December 9, 1932, for constructing a core wall to sound rock at the site of the proposed dike of Quabbin Reservoir on Beaver Brook in the towns of Enfield and Ware.

IX. Watershed Protection

The Commission has purchased some additional properties for protection of the water taken from the Ware River, and in conjunction with the Department of Public Health has continued its studies of possible sources of pollution and the best methods of its elimination. The operation of temporary chlorinating plants installed at two points in the upper watershed of the Ware River to disinfect the effluent from the temporary State Prison Camp and the Rutland State Sanatorium and private hospitals in the Town of Rutland were continued as required.

The Commission, under the provisions of Chapter 262 of the Acts of 1932 authorizing the construction and maintenance of a sewerage system, or systems, for the purpose of maintaining and protecting the purity of the water supplies from the Ware River and Wachusett watersheds, has caused investigation to be made relative to the location of a sewer line and the disposal of sewage.

X. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

XI. Other Reports

The report of the Chief Engineer is herewith presented.

Respectfully submitted,

DAVIS B. KENISTON, *Chairman.*
CHARLES M. DAVENPORT, *Associate Commissioner.*
THOMAS D. LAVELLE, *Associate Commissioner.*

20 Somerset Street, Boston, Massachusetts,
January 14, 1933.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1932.

ORGANIZATION

In numbers the engineering organization has not materially changed during the year.

Karl R. Kennison, Designing Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, preparation of contract specifications, contract and working drawings. He also continued as principal assistant to the Chief Engineer.

Charles L. Coburn and Stanley M. Dore, Assistant Designing Engineers, continued their general supervision of the detailed work of the office; and Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. They have assisted in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Quabbin Reservoir Division, designated until October 25, as the Swift River Reservoir Division.

X. Henry Goodnough, Inc., and J. Waldo Smith continued as consulting engineers. Charles T. Main, consulting engineer of Boston, Dr. Charles P. Berkey, geologist of Columbia University, Arthur A. Shurcliff, landscape architect of Boston, and other experts were employed from time to time.

The employees under the direction of the Chief Engineer at the end of the year and the preceding year were as follows:

	Nov. 30, 1931	Nov. 30, 1932
Headquarters Office, Designing Division	33	36
Holden Office, Wachusett-Coldbrook Tunnel Division	23	22
Hardwick Office, Coldbrook-Swift Tunnel Division	28	30
Enfield Office, Quabbin Reservoir Division	39	47
Total Engineering Force	123	135

The maximum force during the year was 135, during the eight weeks ending August 27, and the six weeks ending November 26. The minimum force was 125, during the two weeks ending December 12, 1931. The average force for the year was 131.

OFFICES

The office of the Chief Engineer and Designing Division was continued in the Metropolitan District Commission Building at 20 Somerset Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Quabbin Reservoir Division was continued in the property of the Commonwealth formerly known as the Frances W. Chandler house on Quabbin Road, and the laboratories for water analysis and for soil testing were continued in the property of the Commonwealth formerly known as the Barlow house, in Enfield.

HEADQUARTERS OFFICE

Summary of the Year's Work

Real Estate. — Reports and recommendations with respect to the purchase of real estate in the Quabbin Reservoir area were submitted to the Commission during the year covering 3,614 acres, making a total to date of 66,723 acres.

PROGRESS OF REAL ESTATE NEGOTIATIONS FOR QUABBIN RESERVOIR

	Total Area Negotiated Including Owners' Offers to Sell to Commonwealth (Acres)	Area not Required (Acres)	Title Vested in Commonwealth (Acres)
Total for Year ending Nov. 30, 1932	3,614	458	3,762*
Total to Nov. 30, 1931	63,109x	6,887x	44,980x
Total to Nov. 30, 1932	66,723	7,345	48,742

Options outstanding Nov. 30, 1932, include 1,014 acres.

Acreage is based partly upon surveys and partly upon information obtained from deeds. x Corrections of the acreage are made from time to time as information is available. See appended table.

*Includes some offered in previous years.

Reports and recommendations were submitted to the Commission with respect to the purchase of real estate for sanitary protection in the Ware River watershed above the intake works at Coldbrook.

Progress of Real Estate Purchases for Ware River Watershed Protection

	Title Vested in Commonwealth (Acres)
Total for year ending Nov. 30, 1932	1,273
Total to Nov. 30, 1931	2,794
Total to Nov. 30, 1932	4,067

Contracts and Specifications. — Working drawings for Contracts 20, 30 and 32 were prepared and issued.

Contract 35 was prepared, for the purchase of electricity at the site of the main dam in Enfield in order that experiments might be made on lowering of the ground water level by pumping from the experimental caisson sunk under Contract 32. The contract was executed June 2.

Contract 37 was prepared, for the purchase of electricity at the site of the dike in Enfield in order that the lowering of the ground water level effectively begun under Contract 32 might be continued. The contract was executed September 21.

Plans and specifications were prepared for Contract 36 for constructing a core wall to sound rock at the site of the dike of Quabbin Reservoir in the towns of Enfield and Ware, by sinking a row of concrete caissons across the bottom of the valley and sealing them to the ledge and to each other. The contract was advertised November 10, for the opening of bids on December 9, 1932.

Inspection and Tests. — E. L. Conwell and Company continued the testing of cement. The Worcester Polytechnic Laboratory continued the testing of concrete cylinders and steel reinforcement bars. The inspection of structural steel work and iron castings furnished under Contract 30 was made by our own engineering force.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey. A recording gage was installed in the Ware River intake works to provide a continuous record of the pond level upstream from the main spillway and to supplement during flood flows the record obtained from the submerged weir station below the dam.

The gaging station on the Chicopee River at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and the United States Geological Survey, and further discharge measurements were made from time to time to define the rating curve more exactly.

The gaging station on the Chicopee River at the Red Bridge plant of the Ludlow Manufacturing Associates was continued in cooperation with that company and further discharge measurements were made from time to time to define the rating curve more exactly.

The gaging station on the Swift River at the plant of the Boston Duck Mills of the Otis Company at Bondsville was continued in cooperation with that company.

Cooperation with the United States Geological Survey in the operation and maintenance of the gaging station on the Connecticut River at Thompsonville, Connecticut, was continued.

In connection with the examination of the waters of the Ware, Swift and Chicopee rivers, observations of flow were continued from time to time and additional temporary gaging stations established as required.

Ware River Diversion

The diversion of Ware River water into Wachusett Reservoir was continued. With minor exceptions, the flow in the river was not sufficient on any day from December 1 to 22, inclusive, 1931, to permit diversion. The first diversion of the year was made December 23, 1931, and the works were operated during the winter and spring months through May 11, inclusive, whenever the flow in the Ware River exceeded 85 million gallons a day. The flow in the river was not sufficient on any day from May 12 to June 14, inclusive, to permit diversion. In the period from June 15 to October 15, inclusive, in conformity with the requirements of the War Department, no water was diverted. The flow was insufficient also on October 16 to 18 inclusive. Commencing October 18, and until the end of the year, November 30, the daily flow in the river was sufficient to permit diversion, but no diversion was made.

The quantity of water diverted during the year was 9,735,200,000 gallons. The maximum daily diversion occurred on April 2, when 682.4 million gallons were taken into the tunnel. The maximum peak rate of diversion attained was 1,200,000,000 gallons per day. The rate of diversion was momentarily increased to this amount in order to test the maximum capacity of the works for diversion easterly into the Wachusett Reservoir as well as the capacity of the shafts to vent accumulations of air in the tunnel.

The intake works were successfully operated during the diversion season under automatic control with one operator on hand only during the daytime.

During August inspections were made of the shaft, the tunnel near the bottom of the shaft, and the steel bulkhead about 2,250 feet west of the shaft. All were found to be in excellent condition.

Design of Structures

Shaft Vents. — As a result of experience gained in testing the venting of air from the shafts during conditions of capacity flow in the tunnel, designs were made for equipping the shaft cover plates in the floor of the head house over Shaft 4 with hinges and automatic latches and for installing a permanent louver in the south window. Designs were also made for an emergency spillway and vent in the top of Shaft 9, to be completed under Contract 20.

Reservoir Flow Line. — The flow line of Quabbin Reservoir was fixed by the Commission December 29, 1931, at an elevation 530 feet above Boston City Base. This base is approximately 0.8 of a foot below minimum low water in Boston Harbor.

Shaft 12. Swift River Intake. — Studies were continued of the high level intake to adapt the designs to the level established for the flow line.

Main Dam and Dike. — Studies were continued of designs for the main dam and dike. The center lines of both structures were located. Plans were made covering general features of both structures.

Caisson Core Wall at Dike. — Designs were made for a concrete core wall from the original surface to sound rock in the bottom of the valley at the site of the dike to be constructed by sinking a row of caissons, each 9 feet thick by 45 feet long. These caissons are designed to be sealed to the ledge and to each other. Twenty-seven caissons will be required supplemented at each end by a short length of wall constructed in sheeted trench. Studies were made of the economical depth of open-cut trench to be first excavated before starting the sinking of caissons and the bottom of the trench in the deepest portion of the valley was fixed at about 45 feet below the brook level, the remaining distance to ledge being about 80 feet. Each caisson was designed with three 4-foot wells, the two end wells being for handling muck and the central well for handling men. A compressed air lock will be required on each well to seal the caisson to the ledge.

Pumping Ground Water. — From data obtained in sinking the experimental caissons at the main dam and dike sites and by analysis of materials from the caissons, borings and test pits, studies were made of the permeability of the foundation materials at both sites. Designs were made for the installation of pump suction intakes beneath the cutting edge on all four sides of the experimental caisson at the dike to allow the installation of pumps in the completed experimental caisson, so that the lowering of ground water by pumping could be continued after this caisson was sunk. All data on the character of the material overlying the ledge and the lowering of the ground water level were prepared for the benefit of prospective bidders for the construction of the completed caisson core wall. Studies were made of the extent to which the ground water may be still further lowered to facilitate the work of sinking the proposed caissons and of methods best adapted to accomplish this lowering. Designs for the core wall include the sinking of the first two caissons from the present brook level and at a sufficient distance from the exploratory caisson so that pumping plants in all three caissons will effectively lower the ground water level over the entire site.

The design of the core wall provides for the extension of a wall 25 feet above the bottom of the open-cut trench, the final filling of all the caisson well openings with impervious soil and the filling of the open-cut trench over and around the tops of the caissons with impervious soil for a minimum thickness of 110 feet at the original

brook level so that the entire site will be drained and ready for the construction of the dike embankment under a subsequent contract.

Main Dam Control Works. — Studies were continued of the control works to be ultimately installed at the downstream end of the river diversion tunnel and the channel walls of the diversion conduit at the downstream tunnel portal were designed anticipating the requirements of future construction. Provision was made for the future installation in these control works, if desired, of a water turbine so that electric power can be generated from the water required to be released under the provisions of Massachusetts Legislation and the requirements of the War Department. In addition to the 48-inch pipe embedded in the tunnel invert under Contract 30 and previously described, a second 48-inch pipe is designed to be laid subsequently on the invert of the main river diversion conduit after it has been plugged, so that there will be two 48-inch outlets leading from the bottom of two wells in the intake shaft just upstream from the center line of the dam. In the control works at the downstream portal these two 48-inch pipes will be cross-connected so that either or both may be made to deliver to the water wheel or other points of discharge. Provision has been made for a considerable variation in the rate discharged and the quantity will be measured through three Venturi meters designed to accommodate these varying rates, the largest meter, 60 inches x 33 inches, the intermediate, 33 inches x 19 inches, and the smallest, 12 inches x 7 inches. All three meter tubes have been installed as a part of the work under Contract 30.

Photographic Records. — Moving pictures were taken from time to time to illustrate the progress of construction work and to record existing conditions in the Swift River valley.

Protection of Water Supply. — Studies were continued of the removal of sewage from parts of Rutland and Holden and the watersheds of the Ware and Quinapoxet rivers, in conformity with permissive legislation, Chapter 262, Acts of 1932.

Cemetery Development. — Studies were continued of the development of the new cemetery which has been named Quabbin Park Cemetery. Additional driveways and landscaping were planned, making the total area in the first development about 18 acres. The arrangement of lots was determined, totalling 1,602 and averaging 16 x 20 feet. Designs were made of a vault with a capacity of 8 caskets. The vault, with an attractive facing of dark weathered stone masonry, was located on the entrance drive. Lot plans were prepared for permanently recording the assignment of burial lots.

Highway Relocation. — Studies were continued of highway relocations which will be required because of the construction of Quabbin Reservoir.

Railroad Valuation. — Valuation studies were made of that portion of the Athol Branch of the Boston and Albany Railroad which will be affected by the construction of the Quabbin Reservoir.

Wachusett–Coldbrook Tunnel Division — Holden Office

The Wachusett-Coldbrook Tunnel Division continued in charge of the construction of the Wachusett-Coldbrook Tunnel section of Quabbin Aqueduct, the work at all shaft heads, and all work in connection with improvements in the Ware River watershed, also of the maintenance and operation of the Ware River intake works. Commencing December 16, 1931, the division took charge of a portion of the surveys for highway relocation in the Quabbin Reservoir area and field studies of materials and methods of construction of the main dam and dike.

Office Work

Monthly estimates were prepared for Contract 31 and final estimates for Contracts 22, 25, 26, 28, 29 and 31. Geologic samples of the rock excavated from the Wachusett-Coldbrook Tunnel were prepared for permanent record and placed in cabinets on the main floor of the Ware River intake works. Miscellaneous data for record drawings of the Wachusett-Coldbrook Tunnel and appurtenant structures were prepared for the Headquarters office. Daily rainfall and temperature records were continued at the White Valley meteorological station. Topographic maps were made covering various possible routes for the location of a trunk sewer

for diverting from the Ware and Wachusett watersheds the sewage from the U. S. Veterans' Hospital and the State Sanatorium in Rutland and from other institutions in Holden and Rutland. Studies were made of the feasibility of various methods of diverting the sewage. Topographic and real estate plans were prepared, and studies made for relocation of highways which will be made necessary by the construction of Quabbin Reservoir. The division cooperated with the Enfield office in these studies of new highways. Real estate plans were prepared of miscellaneous property in the Ware River watershed. Studies were made of materials, comparative costs and methods of construction of the proposed main dam and dike.

Field Work

Lines and grades were given for construction on Contracts 25, 26, 28, 29 and 31. Topographic surveys were continued in connection with studies of various methods of the disposal of sewage and other wastes from hospitals and other institutions in Holden and Rutland and these surveys were extended covering about 140 acres westerly to Coldbrook. Rod soundings were made to investigate the material along the proposed trunk sewer lines. Topographic surveys covering about 2,400 acres were made in connection with studies for the location of new highways in the Quabbin Reservoir area.

Test pits were dug to determine the occurrence of materials suitable for the road construction.

Real estate surveys were made covering about 2,600 acres in the Ware River watershed including various ponds. The setting of property bounds along and in the vicinity of the Wachusett-Coldbrook Tunnel right of way was completed. A total of 241 stone bounds were set during the year.

The State Department of Public Health continued its cooperation with this division in the analysis of samples of water and sewage effluents. Two chlorinator stations on the Ware River watershed, one to chlorinate the sewage effluent from the treatment plant of the temporary Rutland Prison Camp and Hospital, and the other on Mill Brook below the Rutland State Sanatorium and the Central New England Sanatorium, were continued. These stations were operated from December 4 until June 14, and from October 18 to 22.

A labor force averaging 6 men was employed May 24 to June 8 and July 7 to 26, inclusive, for cooperative work with the State Department of Agriculture — Bureau of Plant Industry, for the eradication of currant and gooseberry bushes for the control of pine blister rust in affected areas owned by the Commonwealth in the Ware River watershed.

Operation of Ware River Intake Works

Operation of the Ware River intake works was continued and the division cooperated with the Headquarters office in miscellaneous tests and inspection of the tunnel as required.

Miscellaneous Construction

Minor alterations were made in the mechanical equipment at the Ware River intake works including the installation of a small make-up oil pump designed to run continuously during the diversion period. At the Wachusett outlet works a small water supply pump and pipe lines to hose connections at various points on the grounds were installed and minor changes were made in the electric transformer connections. In the head house at Shaft 4, following experience gained in the venting of air during capacity flow in the tunnel, hinges and automatic hasps were added to the shaft cover plates and a louver installed in one window. Seeding and grassing around the head house at Shaft 4 which had been omitted from Contract 31 by agreement between the Contractor and the Commission was done by the Commission. Shrubbery and trees from the Metropolitan District Commission nurseries in Stoneham, the State Forest Nursery in Amherst and from private nurseries were transported to the site and transplanted by the Commission April 12 to 26.

A small labor force was employed throughout the year on miscellaneous work in caring for the grounds at the Ware River intake and Wachusett outlet and on filling cellar holes, grading and cleaning up at the sites of buildings removed from the Ware River watershed in the towns of West Rutland, Coldbrook and North Rutland. The average number of men employed in this work was 5 and the maximum 16.

Progress of Contracts

Contract 22. — The work of furnishing and installing the tunnel unwatering pump in Shaft 1 under Contract 22 had been practically completed before the beginning of the year as previously reported. On December 11, 1931, the 900 horse-power motor was disconnected from the pump, removed from the bottom of the shaft and stored on the main floor of the outlet building. The pump, left in the bottom of the shaft, was filled with oil on January 11. Drip covers for the better protection of the motor were attached February 5.

The value of work included in contract estimates during the year was $777.95, the final estimate, dated February 13, being for $13,371.76. The contractor's force averaged 1 man for 4 weeks.

Contract 25. — Contract 25, for constructing the superstructure of the Wachusett outlet building at Shaft 1 in the town of West Boylston was continued to completion. As previously reported, the work had been practically completed before the beginning of the year.

The value of work included in contract estimates during the year was $2,017.08, the final estimate, dated January 6, being for $62,329.23.

Contract 26. — Contract 26, for furnishing and installing power and lighting wiring and electrical equipment at the Wachusett outlet works at Shaft 1 in the town of West Boylston was continued to completion. As previously reported, the work had been practically completed before the beginning of the year.

On December 26, 1931, a float switch was installed for automatic control of the deep well sump pump which keeps the pump shaft unwatered. Grilling around the main switchboard and miscellaneous electrical work was completed on January 5.

The value of work included in contract estimates during the year was $796.59, the final estimate, dated February 3, being for $10,685.21.

Contract 28. — Contract 28, for grading the grounds of the Ware River intake building in the town of Barre was continued to completion. As previously reported, the work had been practically completed before the beginning of the year. The stone walls along the highway were completed January 9. Grading, seeding and grassing were completed May 7.

The value of work included in contract estimates during the year was $3,121.44, the final estimate, dated August 6, being for $8,164.14.

Contract 29. — Contract 29, for grading the grounds in the vicinity of the Wachusett outlet building in the town of West Boylston was continued to completion. As previously reported, the work had been practically completed before the beginning of the year. The stone walls, grading, seeding and grassing were completed in July.

The value of work included in contract estimates during the year was $2,453.93, the final estimate, dated August 6, being for $11,852.68.

Contract 31. — Contract 31, for constructing the superstructure of the head house at Shaft 4 in the town of Rutland was continued to completion. As previously reported, the work had been practically completed before the beginning of the year with the exception of seeding and grassing. Due to the lateness of the season, the Commission approved the contractor's request to omit the seeding from the contract and to deduct $50 from the bid price.

The value of work included in contract estimates during the year was $2,969.52, the final estimate, dated January 6, being for $5,689.02.

Coldbrook–Swift Tunnel Division — Hardwick Office

The Coldbrook-Swift Tunnel Division continued in charge of the construction of the Coldbrook-Swift Tunnel section of Quabbin Aqueduct and of river surveys along the Ware, Swift and Chicopee rivers.

Office Work

Tunnel sections were plotted and excavation volumes computed therefrom. Semi-monthly estimates were prepared for Contract 20. Topographic maps were made for an access road to Shaft 12 which will be required after the reservoir is completed. Work was continued on maps of the area along the Ware River extending above the State Highway bridge in Coldbrook and of various mill ponds on the river below the intake works. Geological field notes and specimens

for a permanent geological record were prepared, of the tunnel driven under Contract 20, in the same manner as was done on the Wachusett-Coldbrook portion of Quabbin Aqueduct.

Field Work

Lines and grades were given for construction on Contract 20. About 485 acres of topography were taken along the Ware River both above and below the intake and about 380 acres in the vicinity of Shaft 12 and the tunnel intake. About 70 acres of Quabbin Lake near the intake were surveyed by sounding. The State Department of Public Health continued its cooperation in the analysis of samples of drinking water used in the different contractors' camps and the investigation of mosquito breeding with reference to the prevention of malaria. Taking of samples of concrete for testing was continued and an analysis was made of rock crushed by the Contractor at the various shafts to determine its fitness for tunnel concrete aggregate. Records were continued of the amount of cement used and required to be used at all points of the work. Photographs of the construction work and of rock formations of geological interest were continued. Geological investigations were continued in connection with the tunnel construction. The division also cooperated with the Enfield office in geological investigations in connection with the diversion tunnel under Contract 30, surveys for the spillway and spillway channel at the main dam and for a new highway west of the proposed reservoir. Samples of mud at various depths in the bottom of Quabbin Lake at the tunnel intake were collected for analysis by the Enfield office laboratory. The division cooperated with the United States Coast and Geodetic Survey in the checking of first-order bench marks along the Springfield-Boston line.

Collection of Stream Flow and Water Power Data

The reading of staff gages, set to determine the head at various water power plants on the Ware, Swift and Chicopee rivers and the fluctuations in the level of the ponds on the Ware and Quaboag river watersheds, was continued, and various staff and automatic gages installed and read as required from time to time. Recording gaging stations at White Valley, Old Furnace, Ware, Red Bridge and Bircham Bend were continued. Current meters were rated from time to time as required.

Investigations of the quality of the water in the Ware River were continued in conjunction with the laboratory at Enfield, the principal work of this office being the determination of the necessary hydraulic data.

Progress of Contracts

Contract 20. — Contract 20, for the construction of the Coldbrook-Swift Tunnel section of Quabbin Aqueduct, through the towns of Barre, Hardwick and Greenwich continued in force throughout the year. This tunnel extends 10.4 miles from the end of the completed Wachusett Coldbrook section to the intake from the east branch of the Swift River at Quabbin Lake in the town of Greenwich.

At the end of the year about 45 per cent of the value of the work was completed. This included the excavation of about 38,499 feet of tunnel and the practical completion of the low level intake. About 600 feet of the approach cut to this intake, breaking through into Quabbin Lake, will be excavated under a subsequent contract. A length of 16,332 feet of tunnel remains to be excavated under this contract. The selection, crushing and screening of tunnel spoil for use as concrete aggregates were commenced at all shafts. Excellent progress was made in the excavation of this hard rock tunnel. The average weekly excavation for the year in 7 headings was 98.3 feet per heading, or 100.7 feet omitting the excavation by bucket hoist prior to the installation of the head frame at Shaft 10. The maximum in one heading was 140 feet in the week ending April 23 in the west heading from Shaft 9. The contractor continued to employ local physicians who made weekly reports on the health of his employees and on the sanitary conditions at each of his camps. The contractor also employed a safety engineer to improve working conditions in the tunnel by periodical inspection and improvement of equipment and enlisting the interest of the workmen.

The value of work included in contract estimates during the year was $2,109,400.52, or a total to November 25, the date of the latest estimate, of $2,489,413.13, of which 90% was approved for payment.

Shaft 9. — Excavation at this shaft has progressed as follows:

Location	To Nov. 30, 1931	Year ending Nov. 30, 1932	Total
East heading	574 ft.	6,013 ft	6,587 ft.
West heading	575 ft.	6,103 ft.	6,678 ft.
Total	1,149 ft.	12,116 ft.	13,265 ft.

Tunnel driving was continued throughout the year. The full face method was used except during the time in which soft rock was encountered requiring timbering, when the heading and bench method was used. In the east heading about 60 feet required permanent timbering and about 638 feet of the tunnel roof was treated with gunite to prevent weathering in the seams and scaling off. In the west heading about 54 feet required permanent timbering, about 82 feet required temporary timbering and about 1,410 feet of the tunnel roof was treated with gunite. In the east heading a seam of trap rock 155 feet through was encountered. The average weekly progress of tunnel excavation for the year was 114.5 feet easterly and 116.2 feet westerly, the maximum progress being in the week ending October 22, when 131 feet were excavated in the east section and 138 feet in the west section. The contractor's force averaged 78 men, the maximum being 87 during the week ending August 27. The average number of persons occupying the camp was 14, the maximum population being 29 during 3 weeks in July.

Work on the construction of a crushing and screening plant for aggregate was started March 15. A crusher driven by a 100-horse-power motor was set up and the crushed stone used to improve access to the shaft. The contractor cooperated with the town of Barre to improve the highway approaches to the shaft. At the end of the year about 15,000 cubic yards of crushed aggregate were accumulated and an aggregate washing plant is being erected. Otherwise than stated above, there has been no material change in plant items during the year. One guniting machine and one pump were added. In all 9 pumps were used in connection with tunnel construction, the largest of them having a rated capacity of 600 gals. per min. under 325-ft. head driven by air pressure. The combined compressor capacity was 1,850 cu. ft. per min.

Shaft 10. — Excavation at this shaft has progressed as follows:

Location	To Nov. 30, 1931	Year ending Nov. 30, 1932	Total
East heading	20 ft.	3,790 ft.	3,810 ft.
West heading	24 ft.	3,773 ft.	3,797 ft.
Total	44 ft.	7,563 ft.	7,607 ft.

Excavation was continued until February 5 with shaft sinking equipment and was resumed 5 weeks later after the installation of a head frame and balanced hoisting skips similar to the equipment previously installed at the other three shafts and described in the last report. The full face method was used. About 147 feet in the east heading required permanent timbering. The average weekly progress of tunnel excavation to February 5, with the bucket hoist, was 34.1 feet easterly and 32.9 feet westerly, the maximum progress being in the week ending January 30, when a total of 97 feet was excavated in both headings. Commencing March 12, the average weekly progress was 93.0 feet easterly and 91.3 feet westerly, the maximum progress being in the week ending September 17, when 123 feet were excavated in the east section and 118 feet in the west section. The contractor's force averaged 64 men, the maximum being 82 during the weeks ending May 28 and November 26. The average number of persons occupying the camp was 23, the maximum population being 33 during the week ending October 22.

Two mucking machines were added during the year. A rock crusher driven by a 10-horse-power motor was set up and in operation April 28 and the crushed stone used to surface the access road to the shaft. At the end of the year about 20,000 cubic yards of crushed aggregate were accumulated. Otherwise than stated above, there has been no material change in plant items during the year. Three pumps were added. In all 10 pumps were used in connection with tunnel construction, the largest of them having a rated capacity of 1,100 gals. per min. under 450-ft. head driven by air pressure. The combined compressor capacity was 1,850 cu. ft. per min.

Shaft 11. — Excavation at this shaft has progressed as follows:

Location	To Nov. 30, 1931	Year ending Nov. 30, 1932	Total
East heading	423 ft.	5,420 ft.	5,843 ft.
West heading	423 ft.	5,770 ft.	6,193 ft.
Total	846 ft.	11,190 ft.	12,036 ft.

Tunnel driving was continued throughout the year. The full face method was used after January 10. About 200 feet in the east heading required temporary timbering. The average weekly progress of tunnel excavation for the year was 103.5 feet easterly and 109.9 feet westerly, the maximum progress being in the week ending January 2, when 115 feet were excavated in the east section and 135 feet in the west section. The contractor's force averaged 74 men, the maximum being 82 during the weeks ending October 8 and November 19. The average number of persons occupying the camps was 27, the maximum population being 36 during the week ending April 9.

Two mucking machines were added during the year. A rock crusher driven by a 60-horse-power motor was set up and in operation March 13. At the end of the year about 45,000 cubic yards of crushed aggregate were accumulated. Otherwise than stated above, there has been no material change in plant items during the year. Four pumps were added. In all 8 pumps were used in connection with tunnel construction, the largest of them having a rated capacity of 300 gals. per min. under 490-ft. head driven by air pressure. The combined compressor capacity was 1,850 cu. ft. per min.

Shaft 12 and Swift River Intake. — Excavation at this shaft has progressed as follows:

Location	To Nov. 30, 1931	Year ending Nov. 30, 1932	Total
East heading	406 ft.	4,924 ft.	5,330 ft.
West heading	167 ft.	5 ft.	172 ft.
Portal	–	89 ft.	89 ft.
Total	573 ft.	5,018 ft.	5,591 ft.

Tunnel driving was continued throughout the year. The contractor designed and built a drag line mucker which was used in the east heading commencing January 24. The motor carriage is about 15 feet long. The rear belt-conveyor is about 40 feet long so that a train of cars can be backed under it. An extension was put on the drag line boom March 7, making it 58 feet long and making the total length about 113 feet. About 119 feet in the east heading required permanent timbering. The average weekly progress of tunnel excavation for the year was 93.5 feet in the east heading, the maximum progress being 136 feet in the week ending August 20.

On April 28 the contractor started to unwater the portal cut. Excavation in the lower intake was resumed on May 25 and the tunnel was excavated easterly from the portal for a distance of 89 feet by the heading and bench method June 2 to 28. No excavation was done in the west heading from Shaft 12, the remaining 58 feet required for holing through being left as a protection against inflow of water from the area of the lower intake.

The work of concreting the lower intake and the cut and cover section leading to the tunnel portal was commenced July 19 and completed October 4, including a length of 10 feet of the tunnel invert and 6 feet of the sidewalls and arch inside the tunnel portal. Riprap and paving at the lower intake were placed during the latter part of September and backfill around the intake structure and the cut and cover section early in October. The material for this backfill was obtained by flattening the side slopes of the portal cut.

The contractor's force averaged 58 men, the maximum being 75 during the weeks ending September 3 and 17. The average number of persons occupying the camps was 26, the maximum population being 49 during the week ending August 27.

One air compressor with a capacity of 750 cu. ft. per min. was added during the year; also a 600 gals. per min. low head pump for use at the lower intake. A rock crusher driven by a 60-horse-power motor was set up and in operation January 15. At the end of the year about 25,000 cubic yards of crushed aggregate were accumulated. An aggregate washing and separating plant was put in operation July 2. Otherwise than stated above, there has been no material change in plant items during the year. The combined compressor capacity was 2,050 cu. ft. per min.

The total work done and materials furnished to date under the principal items of Contract 20 are as follows:

	Shaft 9	Shaft 10	Shaft 11	Shaft 12 and Intake
Earth excavation for shafts (cu. yds.)	84	318	225	*
Rock excavation in shafts and in tunnel within 50 ft. of shafts (cu. yds.)	2,310	3,617	2,660	1,445
Excavation in tunnel, except within 50 ft. of shafts (cu. yds.)	84,736	47,551	75,930	35,923
Shaft and tunnel drainage (lin. ft.)	3,390	2,170	3,138	1,403
Earth excavation in open cut (cu. yds.)	—	2,500	1,803	35,429
Rock excavation in open cut (cu. yds.)	—	435	106	2,121
Forms for concrete linings of shafts (lin. ft.)	178	397	258	—
Concrete masonry in shafts (cu. yds.)	400	929	611	—
Concrete masonry not in shafts or tunnel (cu. yds.)	—	—	1	1,062
Permanent timbering in tunnel (M ft. B.M.)	25	6	—	25
Temporary timbering in tunnel (M ft. B.M.)	6	—	4.5	—
Portland cement (bbls.)	1,106	1,410	898	2,212
Gunite protective coating of tunnel rock (lin. ft.)	1,943	—	—	—
Refilling and embanking (cu. yds.)	—	1,625	—	2,753
Miscellaneous cast iron, wrought iron and steel (lbs.)	23,400	3,415	—	5,911

*Included in item, "Earth excavation in open cut."

Electric power for all contract requirements was purchased by the contractor. The total consumed at the different shafts was as follows:

	K.W.H.
Shaft 9	2,167,200
Shaft 10	2,718,800
Shaft 11	2,577,600
Shaft 12	1,635,800
Total	9,099,400

Contract 24. — Contract 24, for constructing the superstructure of the building for the Ware River intake works at Shaft 8 of the Wachusett-Coldbrook Tunnel in the town of Barre was continued to completion. As previously reported, the work had been practically completed before the beginning of the year.

The value of work included in contract estimates during the year was $279.64, the final estimate, dated January 6, being for $70,114.04.

Quabbin Reservoir Division — Enfield Office

The Quabbin Reservoir Division, previously designated as the Swift River Reservoir Division, continued in charge of the field work in the Swift River valley in connection with the proposed Quabbin Reservoir including topographic and real estate surveys, cemetery removal work, and the soil testing and water analysis laboratories. The division also continued in charge of construction work at the main dam and dike sites, Quabbin Park Cemetery, and the Ware-Belchertown highway relocation.

Miscellaneous Office Work

Semi-monthly estimates for Contract 21, monthly estimates for Contracts 23, 30, 32 and 34, and final estimates for Contracts 21, 32 and 34 were prepared. Topographic and real estate plans were prepared and studies made for relocation of highways which will be necessary west of Quabbin Reservoir. Topographic plans were completed for the layout of roadways in Quabbin Park Cemetery, and revised topographic plans of the dike site were made. Photographs of the progress of construction carried on under the supervision of this and other divisions were taken by this division. Meteorological records were continued in Enfield.

Miscellaneous Field Work

Lines and grades were given for construction on Contracts 21, 23, 30, 32 and 34. A detailed topographic survey was made for use in a contract for the caisson core wall at the dike site. The lowering of the ground water level at the dike site under Contract 32 was, at the completion of the contract, continued by the division, using rented pumping equipment installed in the completed exploratory caisson and in the adjacent sump; daily readings of ground water level in numerous test wells were taken. Electric wiring and pumping equipment was installed in the completed experimental caisson at the dam site and the pumps were operated for 2 months commencing June 25, as an experiment in lowering the ground water level. Test pits were dug in connection with the investigation of the porosity of foundation materials at the main dam and dike and of materials for use in the construction of the proposed embankments. Topographic and real estate surveys and cross sections were made for the location of new highways west of Quabbin

Reservoir and test pits were dug to determine materials suitable for their construction. Subsurface investigations were made by pipe casings and test pits at and near the site of the proposed main dam spillway and spillway channel.

Reservoir — General

Topography. — No progress was made during the year on the general topographic maps within and adjacent to the proposed reservoir. To date 25,970 acres or 40.6 square miles have been surveyed. About 24,200 feet of the drainage divide were surveyed.

Real Estate. — Additional property described in applications by owners for sale of real estate was located and sketches made showing the approximate location. Comprehensive real estate surveys and analyses and descriptions of deeds were continued. Real estate surveys during the year cover 579 acres, making a total to date of 58,889 acres or 92.01 square miles. Of this total, 57,745 acres have been plotted at a scale of 1 inch = 200 feet. No additional final tracings were made. Preliminary taking plans were made covering about 30,000 feet of highway location surveyed in Belchertown and Pelham.

Photography. — The photographing of buildings and cemetery lots within the area to be affected by the proposed reservoir and the making of record prints were continued. During the year 73 photographs of buildings, 99 of cemetery lots, and 246 of the progress of construction carried on under the supervision of this and other divisions were taken. 220 photographs of property in the Ware River watershed were also taken.

Cemetery Removals. — With the completion of Quabbin Park Cemetery and the prohibition of further interments in existing cemeteries in the reservoir area, interments in the new cemetery and general removal of bodies from existing cemeteries were begun. The removal of bodies, headstones and monuments has been done by this division with labor engaged directly for this work. Equipment for the work of removing and resetting monuments was supplemented during the year by a portable concrete mixer. During the year work has progressed as shown in the following table:

QUABBIN PARK CEMETERY

		To Nov. 30, 1931*	Year ending Nov. 30, 1932	Total
Burial lots assigned in exchange		0	208	208
Burial lots purchased		0	1	1
Number of releases executed of rights in old lots in Quabbin Reservoir area	to Q. P. Cemetery	0	28	28
	to other cemeteries	80	31	111
Bodies removed from Quabbin Reservoir area	to Q. P. Cemetery	0	62	62
	to other cemeteries	527	171	698
Burials, not reinterments		0	9	9
Headstones moved	to Q. P. Cemetery	0	42	42
	to other cemeteries	235	82	317
Monuments moved	to Q. P. Cemetery	0	7	7
	to other cemeteries	95	22	117

*Quabbin Park Cemetery was not completed and ready for use until August 25, 1932.

Fire Protection. — The fire fighting equipment housed at Enfield was continued in readiness for service at all times. Five assistants in the division office were reappointed as deputy forest wardens in each of the towns affected by the reservoir. The equipment and personnel responded during the year to calls for assistance at 8 forest fires which burned over a total area of 326 acres. The apparatus also responded to fires in 7 buildings.

Laboratories

Soil Testing Laboratory. — The work of exploring, collecting and testing materials to determine their suitability for use in the construction of the proposed main dam and dike was continued. New equipment was added to the laboratory as testing methods were expanded to include new studies and to keep pace with current developments in soil engineering. Investigations were continued of the extensive and deep deposits of glacial till forming the ground moraine overburden

on the west side of Beaver Brook valley north of the dike site and on the west side of the Swift River north of the main dam site. The investigations included studies of deposits of modified drift on the east side of the river above the main dam site. In connection with the construction of the Swift River diversion works, tests were continued of top soils for the impervious portions of the cofferdams. Tests were also made of top soils, in areas north and east of Enfield, available for use in the impervious portions of the proposed cut-offs at the dam and dike. In connection with percolation studies of materials in the main dam and dike foundations, tests were made of permeability, porosity, and grain size of samples from the exploratory caissons, open cuts and test pits; and in cooperation with the Headquarters office all boring samples were analyzed and classified for size distribution.

Chemical and Bacteriological Laboratory. — The collecting and analyzing of water samples in preparation for records and reports were continued in cooperation with the Headquarters office and with assistants from the Coldbrook-Swift Tunnel Division. Samples of the water supplies of contractors engaged on work in this and other divisions and of miscellaneous supplies on property controlled by the Commission were collected and analyzed periodically. Studies were made of the chemical stability of materials found in the bottom of Quabbin Lake near the intake to Quabbin Aqueduct.

Miscellaneous Construction

Work of clearing the sites of the main dam and dike was done by labor employed by the Commission.

Work of developing Quabbin Park Cemetery under Contract 34 was supplemented by clearing, grubbing and grading the cemetery area. In clearing, selected trees and bushes were left standing to retain the natural beauty of the cemetery development. New planting included 390 white pines and 75 red pines transplanted from the reservoir area, and 50 arbor vitae, 100 Norway and blue spruce and 54 red pines from nursery stock.

A concrete receiving vault having a capacity for 8 bodies was constructed near the entrance to the cemetery. Dark weathered stones were gathered from walls on property of the Commonwealth for use in facing the entrance walls, framing the heavy steel doors.

A water supply for the cemetery was installed consisting of a collecting well on property of the Commonwealth, about 6,000 feet of ¾-inch distribution pipe, a pressure tank located at a high point in the cemetery and 16 self-closing faucets located at convenient points along the cemetery roadways.

Two hundred tons of trap rock crusher screenings were applied to the surfaces of driveways in Quabbin Park Cemetery. One hundred tons were purchased and stored for future maintenance of the surface.

The average force employed on cemetery development during 33 weeks ending August 20 was 12 men, the maximum being 25 during the week ending June 18.

Progress of Contracts

Contract 21. — Contract 21, for constructing a relocated portion of the Ware-Belchertown highway in the towns of Ware and Belchertown was continued to completion. The Department of Public Works cooperated in the construction of this new state highway and paid a portion of the cost, namely the cost of surfacing and guard rails. All excavation and embankment to sub-grade was completed December 11, 1931, except a small amount remaining at the approaches to the bridge across the Swift River. Gravel sub-base was also completed at that time for about 12,000 feet at the west end, 1,650 feet at the east end, and at connections with two main crossroads. This included all sections required to be left passable for winter traffic. Both abutments, the two piers, and the westerly deck were completed before February 2. Work on the roadway was stopped for the winter from December 11 to April 13 and on the bridge from February 2 to March 30. The bridge was completed on May 26.

At the start of the work in the spring, three shovels were operated in gravel borrow pits and the placing of gravel base and shoulders was advanced rapidly. Broken stone for the roadway surface was received by rail at the West Ware siding where the Contractor had installed unloading equipment. Placing the

stone was started on May 1 and carried on continuously from both ends to completion near the midpoint at West Ware, July 15. An average of 600 tons per day of this surface material was placed. The top course was placed 2½ inches thick throughout. The excellent character of the gravel sub-base made it possible to decrease the thickness of the broken stone base course from 4½ inches to 3½ inches for nearly three quarters of the entire length. Bituminous asphalt used to penetrate the broken stone was applied at the rate of 2¼ gallons per square yard followed by a seal coat at ½ gallon per square yard, except that on grades of 3% or more a single application was made at 2¾ gallons per square yard. The installation of cable guard rails was started on July 11, and completed on August 22.

Entrance drives to various properties along the highway were provided and side slopes in the vicinity of dwelling houses, Quabbin Park Cemetery and other conspicuous points, including the slopes of two heavy cuts, were covered with loam and seeded. In addition all side slopes and cuts and fills were seeded. The approaches of two intersecting highways were treated with applications of tar. At the east end to improve the intersection with the Ware-Enfield road, a long radius connection, 290 feet long, was constructed and surfaced with bituminous macadam the same as the main highway and a length of 650 feet of the Ware-Enfield road was re-surfaced.

The broken stone surface is 24 feet wide with 3-foot gravel shoulders. The maximum grade is 6% and the sharpest curve has a radius of 1,100 feet.

The Department of Public Works assigned an inspector to the work to inspect the placing of the roadway surface and guard rails, and the general cleaning up of the work.

The value of work included in contract estimates during the year was $169,024.36, the final estimate, dated October 11, being for $225,707.19, of which $95,726.94 was paid by the Department of Public Works. The contractor's force averaged 45 men for 32 weeks, the maximum being 133 on December 2, 1931.

Important items of plant added during the year for the work of surfacing were one stone unloader, one distributor mounted on truck chassis and one crane with ½-cu. yd. bucket.

The total work done and materials furnished to date under the principal items of Contract 21 are as follows:

Roadway earth excavation	86,078 cu. yds.
Bridge excavation	1,644 " "
Ledge excavation	7,090 " "
Earth borrow	43,991 " "
Rubble concrete masonry	998 " "
Plain concrete masonry	225 " "
Reinforced concrete masonry	730 " "
Broken stone	28,333 tons
Bituminous material	201,400 gals.
Gravel borrow	30,440 cu. yds.
Fine grading	181,629 sq. yds.
Cable guard rails	17,058 lin. ft.
Trench excavation	4,512 cu. yds.

Contract 23. — Contract 23, for making borings in the towns of Belchertown, Enfield, Ware, Greenwich and Hardwick continued in force throughout the year. The work was practically confined to the exploration of overburden in the vicinity of the main dam and dike sites.

The value of work included in contract estimates during the year was $11,349.18 or a total to November 10, the date of the latest estimate, of $30,773.25, of which 90% was approved for payment. The contractor had one drilling rig in operation during the year and employed an average of 2 men.

Contract 30. — Contract 30, for constructing the stream control works at the main dam of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware continued in force throughout the year. Rock excavation in open cut at the downstream portal was started on December 3, 1931. All work of tunnel excavation was carried on from the downstream portal. Commencing January 4, a top heading from about 2 feet below the springing line of the arch to the roof was excavated for a distance of 840 feet followed by a pilot heading about 6 feet square to the upstream portal, holing through on April 8. This upper drift was then enlarged and completed about April 20. Excavation of the lower bench was started at the downstream portal April 30 and completed June 26. A small

Contract 30. — Main Dam River Diversion Tunnel, Downstream Portal, Drill Carriages Used in the Tunnel Excavation.

Contract 32. — In the Working Chamber of the Exploratory Caisson at the Dam Site after Underpinning from the Cutting Edge to Ledge, 102 feet below the surface.

quantity of rock excavation near the downstream portal as well as a considerable quantity of earth excavation in the downstream channel was left as a ramp for handling materials out of the tunnel by truck until September 15 when excavation of the downstream channel was again started and, together with the remaining rock excavation in the downstream portal, completed November 16 except for breaking through to the river.

Excavation of rock in the upstream approach cut was continued. The upstream portal was moved back into the hill about 110 feet and the excavation for the cut and cover section of the conduit increased accordingly on account of the occurrence of a disintegrated condition of the ledge surface. This excavation was completed on June 28.

At the shaft, earth excavation was started May 24, and on April 19, rock excavation was started with a hole about 8 feet square as an upward drift from the tunnel. This hole broke through to the surface on June 9 and the remaining shaft excavation was carried on intermittently and completed on August 12.

Sound rock was encountered for the entire distance between portals and no timbering was used. Drilling was done from drill carriages mounted on automobile truck bodies and mucking by a 1-cubic yard electrically-operated shovel. Muck was hauled out by gasoline-operated trucks. The average progress in the top heading was 8.6 feet or 163 cu. yds. per day and in the bench excavation 16.7 feet or 234 cu. yds. per day. A trench about 7 feet wide was excavated in the tunnel floor for the placement of a steel pipe from a riser in the shaft to the downstream portal. This pipe was lined with gunite in sections alongside the trench before placing, 48 inches inside diameter. The installation was completed September 7, and satisfactory tests for tightness made.

Materials from the earth excavation suitable for concrete aggregate were stored and a plant for crushing, screening and washing this material was operated from June 17 to October 14. The wash water was discharged into a settling basin, only the overflow from the basin entering the river. All fine and coarse aggregates used on the work were obtained from this plant. Cement was delivered to the job first in bags on June 25. From August 13 to November 30, for practically all of the major concreting operations, cement was delivered in bulk. For the greater part of the work of concreting, aggregates were belt-conveyed to an aggremeter located in the upstream channel. Materials were conveyed by trucks containing four batches of 1 cubic yard each to 1-cubic yard mixers located near the point of deposit. For tunnel sidewalls and arch the mixed concrete was delivered through pneumatic conveyers and placers. Lining of the approach channel was commenced July 1. Tunnel lining was commenced August 12 and completed November 4. All concrete work, including the cut and cover section of the conduit, the entrance portal, tunnel invert sidewalls and arch, concrete walls and Venturi tubes at the outlet, was completed, except the lining of the shaft above elevation 394 and a small portion of the lining of the approach channel. The maximum daily output of concrete was 380 cu. yds. on August 5 and 6, using two mixers.

The construction of rolled cofferdam embankments from materials obtained from the various excavations was stopped for the winter December 3, 1931, resumed September 15 and completed about November 15. Surplus rock from the tunnel excavation not used in constructing the cofferdams was placed in storage piles downstream for subsequent use in the toes of the dam. Placing of rolled impervious blanket on the upstream face of the upstream cofferdam was carried to completion coincident with the cofferdam fill, material being secured from storage piles from the stripping operations and from a borrow area above the dam site. Some of the material excavated from the discharge channel was deposited as backfill over the cut and cover section of the conduit and puddled to insure a compact fill. The maximum number of trucks used was 14.

At the end of the year about 90% of the work was completed, the work remaining to be done consisting of completing the shaft lining, paving around the upstream portal and breaking through to the river both upstream and downstream.

The value of work included in contract estimates during the year was $405,526.65 or a total to November 10, the date of the latest estimate of $471,484.15, of which 90% was approved for payment. The contractor's force averaged 75 men, the maximum being 166 on July 21 and 22. The average number of persons occupying

the camp was 36, the maximum population being 60 during the two weeks ending August 1.

The following items of plant equipment were added during the year:

1 Crushing, screening and washing plant
1 1¼-cu. yds. travelling crane
1 Aggremeter
2 1-cu. yd. mixers
2 14-cu. ft. pneumatic concrete placers

The total work done and materials furnished to date under the principal items of Contract 30 are as follows:

Excavation in shaft and tunnel	38,000	cu. yds.
Earth excavation in open cut	275,700	" "
Rock excavation in open cut	23,430	" "
Refilling and embanking compacted in 6-inch layers	130,300	" "
Other refilling and embanking	110,740	" "
Concrete masonry in tunnel and open-cut conduit	12,520	" "
Portland cement	27,202	barrels

Contract 32. — Contract 32, for constructing two exploratory caissons, one at the main dam and one at the dike of Quabbin Reservoir, in the towns of Enfield and Ware, was continued to completion. Sinking the caisson at the dam site was continued by open dredging to December 5, 1931, and thereafter under compressed air until bedrock was reached on January 9 at elevation 313.8, a depth of about 70 feet below the river level, 86.2 feet below the bottom of the open-cut trench and 102 feet below the original surface. The caisson was left projecting 11.6 feet above the bottom of the open-cut trench. The caisson was landed practically plumb, the maximum variation in elevation between the four corners of the 12 x 32 foot-section being 0.2 foot. The rate of sinking was 11.68 feet per 24-hour day during the actual sinking by open dredging and 2.13 feet per 24-hour day during actual sinking under air pressure. Concrete underpinning walls were built from the cutting edge to sound ledge at all points, all loose and seamy rock removed, pipes placed for subsequent drilling of grout holes and a concrete seal was poured on January 14 to a height about 12 feet above the cutting edge. Grouting operations were completed February 9. The maximum air pressure used was 33 lbs.

Attempts to reduce the pressure by experimental pumping from a central pump well connected to screen chambers in the sides and ends of the cassion indicated that air escaping from under the cutting edge clogged the screens with fine material to such an extent that the ground water level could not be lowered materially during the sinking operations. After the caisson was sunk, pump inlets and screens were cleaned of the fine material and a flow of 650 gallons per minute into the pump well was obtained.

Equipment used at the dam site was removed to the dike site, the shoe of the dike caisson placed practically at the original surface only about 1 foot above the ground water level and concrete poured to a height of 25 feet on February 8. The caisson was sunk to a depth of about 9 feet by open dredging. The coarse compact nature of the material encountered at this point, 8 feet below the water level, made it necessary to place the caisson under air. Sinking under air was started February 27, and reached a depth of 63 feet on April 14. The rate of sinking to this depth under air was 1.97 feet per 24-hour day of actual sinking.

Experiments in pumping from a central well through screen chambers in the sides and ends of the caisson were continued at the dike caisson but the perforated steel plate screens, flush with the concrete surface, used at the dam site were omitted, the screen pockets being filled with graded material in direct contact with the outside earth. However, the experience at the dam site was repeated in the clogging of the intakes by fine material apparently due to air escaping from beneath the cutting edge. Furthermore, the screen openings proved to be a disadvantage on account of boulders crowding into them and increasing the frictional resistance.

Since the estimated depth to bedrock was 123 feet below the ground water level, a sheeted pump sump about 26 feet square was excavated at a point about 100 feet from the caisson to a depth about 50 feet below the ground water level, in which pumps for lowering the ground water level could be installed. To facilitate the excavation of this pump sump, the sinking of the caisson was stopped, and pumps were installed in one of the working chambers and used to lower the ground water level ahead of the sump excavation. Upon completion of the sump, pumps

were installed therein and operated continuously from May 27 until the caisson was completed at a rate of about 1300 gallons per minute.

After these pumps were put in operation and before sinking the caisson was resumed, wells were excavated by cribbing at the sides and ends of the caisson to uncover the screen chambers. These were filled with concrete except for small pipe openings and all baffle plates and other obstructions tending to increase the frictional resistance to sinking were removed. Sinking under air was continued, generally through coarse water-bearing gravel with many boulders, from June 7 to July 21, when the caisson landed on sound ledge at elevation 292.4, after sinking a depth of 123.9 feet. The caisson was left projecting about 8 feet above the surface. It was landed inclined 12 inches in the total height of 132 feet and about 12 inches average to one side of the line as given. The average rate of sinking from the 63-foot depth was 2.32 feet per 24-hour day.

Before sealing the caisson to ledge, four pump intakes or chambers filled with graded gravel were constructed below the cutting edge, one on each side and each end of the caisson. Pipe connections were placed through the concrete seal from these chambers to one of the wells in the caisson to be used as a pump well. The walls were then underpinned to sound ledge and pipes for subsequent drilling of grout holes were placed. The concrete seal was poured on July 29 to a height about 12 feet above the cutting edge. The maximum air pressure reached 48 lbs. Grout holes were drilled but grouting was left to be done under a subsequent contract.

The connection by piping of a caisson well with the intakes under the cutting edge was made for use primarily in lowering the ground water level during a subsequent contract. Connections were also made so that pumps in this well could take water from the intake pipes originally provided in the sides and ends of the caisson. Electric wiring and piping was installed to provide for the installation of two vertical motor-driven pumps under a subsequent contract. In order to continue the lowering of the ground water level in preparation for such a contract, one pump with a capacity of 1200 gallons per minute was installed and operated and after the completion of the contract its operation was continued by labor employed on force account. This pump was transferred to the caisson from the pump sump leaving a pump of 500 gallons per minute capacity in the sump which was also continued in operation after the completion of the contract.

The value of work included in contract estimates during the year was $150,340.83, the final estimate, dated September 20, being for $162,838.33. The contractor's force averaged 33 men, the maximum being 70 on July 9. No important new items of plant were added during the year.

Contract 34. — Contract 34, for constructing driveways in Quabbin Park Cemetery in the town of Ware was continued to completion. The work originally contemplated, of which 80% had been completed at the beginning of the year, was extended by the addition of 2,000 feet of roadway in an addition to the cemetery development. Work was resumed on April 12, following the winter shut-down. Clearing of the driveway areas in the cemetery extension was completed April 17. Top soil was stripped with a ½-cubic yard gasoline shovel and stored for later use in covering the side slopes, from April 13 to April 16. Grading and excavation of the cuts to sub-grade were completed April 27, the material being hauled to the embankment fills in trucks. The entire work including culverts and surfacing of the roadway, covering side slopes with loam, and storing surplus loam for subsequent use, was completed May 18.

The value of work included in contract estimates during the year was $5,209.02, the final estimate, dated October 8, being for $7,842.94. The contractor's force averaged 14 men for 5 weeks, the maximum being 23 on April 26.

Contract 35. — Contract 35, for the purchase of electricity for experimental work at the dam site was executed June 2 with the New England Power Company. Electric power was purchased for use in experimental pumping. The total power furnished was 22,675 kilowatt-hours, costing $453.50.

Contract 37. — Contract 37, for the purchase of electricity for continuing pumping operations begun under Contract 32 at the dike site in Enfield was executed September 21 with the New England Power Company. The work of pumping was taken over by the division on September 21 and continued to date with electric

power purchased under this contract. The total power furnished was 95,500 kilowatt-hours.

Geological Data

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State." Such information is being prepared for publication in a subsequent report.

List of Drawings and Tables Appended Hereto

Location of Real Estate Acquired for Quabbin Reservoir.
Takings of Real Estate (and Water Rights).
Status of Contracts Completed between Nov. 30, 1930 and Nov. 30, 1932.
Status of Contracts in Force on Nov. 30, 1932.

For General Plan of Metropolitan Water Supply and Key Plan and Profile of Wachusett-Coldbrook Tunnel, see Second Annual Report. For data on Contracts Completed Prior to Nov. 30, 1930, and for Key Plan and Profile of Coldbrook-Swift Tunnel, see Sixth Annual Report.

Respectfully submitted,
Frank E. Winsor, *Chief Engineer.*

20 Somerset Street, Boston, Mass.
December 15, 1932.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
Administration, *Commissioners' Office:*		
Salaries, Commissioners	$10,500.00	$66,612.80
Salaries, Clerical	11,840.83	60,946.24
General Legal Expense	0.00	1,377.80
Furniture and Fixtures	80.22	2,162.78
Rent and Upkeep	2,162.88	13,716.87
Automobile Purchase	0.00	1,988.90
Automobile Maintenance	325.68	1,927.02
Miscellaneous Expense (undistributed)	1,061.33	10,045.99
Advertising	749.93	5,043.52
Printing and Blueprinting	777.78	5,422.77
Stationery and Office Supplies	219.05	1,312.17
Postage	140.50	603.05
Total Administration, Commissioners' Office	$27,858.20	$171,159.91
Engineering, *Headquarters' Office:*		
Salaries, Engineering	$78,552.01	$471,692.10
Salaries, Clerical	9,400.49	56,078.90
General Consultant Expense	8,640.59	107,613.93
General Legal Expense	0.00	53,160.29
Furniture and Fixtures	433.38	12,116.19
Laboratory Equipment	0.00	1,961.00
Laboratory Supplies	0.00	2,071.94
Rental of Equipment	0.00	3,370.02
Engineering Instruments	53.90	1,027.96
Rent and Upkeep of Boston Office	11,407.28	62,954.60
Rent and Upkeep of Springfield Laboratory	0.00	3,950.54
Automobile Purchase	0.00	2,675.60
Automobile Maintenance	325.77	2,816.20
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	860.97	18,726.25
Printing and Blueprinting	557.43	12,644.06
Stationery and Office Supplies	468.80	3,377.42
Postage	255.00	1,104.58
Total Engineering, Headquarters' Office	$110,955.62	$819,646.21
Unassigned:		
Unassigned Supplies and Equipment	$–38.79	$604.72
Total Unassigned	$–38.79	$604.72
Total General Overhead	$138,775.03	$991,410.84

Distribution of General Overhead

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
Administration, *Commissioners' Office:*		
Wachusett-Coldbrook Tunnel	$3,362.28	$62,776.14
Coldbrook-Swift Tunnel	2,307.22	13,177.95
Quabbin Reservoir	10,763.44	69,992.93
Main Dam and Dike	11,425.26	16,522.61
Southern Sudbury Emergency Supply	0.00	8,690.28
Total Administration, Commissioners' Office	$27,858.20	$171,159.91
Engineering, *Headquarters' Office:*		
Wachusett-Coldbrook Tunnel	$12,760.47	$258,024.24
Coldbrook-Swift Tunnel	9,510.26	56,052.86
Quabbin Reservoir	43,020.41	406,745.19
Main Dam and Dike	45,664.48	65,415.95
Southern Sudbury Emergency Supply	0.00	33,407.97
Total Engineering, Headquarters' Office	$110,955.62	$819,646.21

Wachusett-Coldbrook Tunnel Section of Quabbin Aqueduct, Ware Supply

General Overhead:		
Administration	$3,362.28	$62,776.14
Engineering	12,760.47	258,024.24
Total General Overhead	$16,122.75	$320,800.38
Engineering:		
Salaries, Engineering and Clerical	$10,334.34	$383,380.54
Consultant Expense	390.19	7,574.16
Labor	938.00	1,432.00
Furniture and Fixtures	559.87	2,240.89
Engineering Instruments	45.14	7,739.81
Rent and Upkeep	2,126.70	12,726.89
Automobile Purchase	1,455.00	9,948.47
Automobile Maintenance	1,796.35	14,308.09
Contracts for Investigations and Surveys	0.00	18,640.69
Miscellaneous Expense (undistributed)	1,518.66	8,691.29
Advertising	0.00	6.05
Printing and Blueprinting	55.71	847.14
Stationery and Office Supplies	347.40	2,549.85
Postage	42.02	318.84
Total Engineering	$19,609.38	$470,404.71
Real Estate, *General Construction:*		
Legal and Expert Expense	$664.22	$5,497.14
Consultant Expense	61.26	455.66
Labor	230.75	1,137.30
Miscellaneous Expense (undistributed)	338.58	584.10
Printing and Blueprinting	2.55	43.48
Purchases and Settlements	5,611.00	120,700.71
Taxes	322.90	2,900.87
Maintenance of Real Estate	45.74	563.88
Police Protection, Labor	6.00	31.00
Fire Protection, Equipment	0.00	30.97
Special Agents, Salaries	2,460.00	10,653.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	319.00	1,222.50
Automobile Maintenance	272.44	1,774.41

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
Miscellaneous Expense (undistributed)	$204.84	$1,022.17
Printing and Blueprinting	0.00	7.89
Stationery and Office Supplies	3.43	3.43
Postage	2.00	12.36
Total Real Estate	$10,544.71	$146,758.54
WARE WATERSHED PROTECTION:		
Salaries, Engineering and Clerical	$12,312.08	$45,866.05
Legal and Expert Expense	1,163.06	9,661.12
Consultant Expense	0.00	763.70
Labor	1,967.91	8,318.79
Contracts	0.00	4,395.51
Miscellaneous Expense (undistributed)	934.80	2,200.83
Printing and Blueprinting	33.99	288.99
Stationery and Office Supplies	6.00	6.00
Installed Equipment	3.06	2,046.96
Purchases and Settlements	49,293.13	569,101.97
Taxes	886.04	11,893.37
Maintenance of Real Estate	0.00	132.81
Automobile Maintenance	559.85	581.48
Total Ware Watershed Protection	$67,159.92	$655,257.58
WARE DIVERSION DAMAGES:		
Salaries, Engineering and Clerical	$13,001.54	$48,750.88
Legal and Expert Expense	979.33	1,811.57
Consultant Expense	7,815.80	10,805.45
Labor	140.70	2,174.03
Laboratory Equipment	4.39	106.86
Laboratory Supplies	31.14	59.02
Engineering Instruments	25.38	491.98
Rental of Equipment	5.00	182.25
Automobile Maintenance	1,164.25	1,234.77
Contracts for Investigations and Surveys	0.00	63.27
Materials of Construction	0.00	136.51
Miscellaneous Expense (undistributed)	808.42	5,376.20
Printing and Blueprinting	130.56	256.20
Postage	0.00	5.75
Purchases and Settlements	25,450.00	47,950.00
Total Ware Diversion Damages	$49,556.51	$119,404.74
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 4, Sinking Shaft 5 and driving 1,367 linear feet of tunnel	$0.00	$290,581.99
Contract No. 8, Sinking Shafts 6 and 7 and driving 3,062 linear feet of tunnel	0.00	456,784.26
Contract No. 10, Construction and maintenance of Transmission line for Wachusett-Coldbrook tunnel contracts	0.00	119,547.39
Contract No. 12, Sinking Shafts 2, 3 and 4 and driving 3,810 linear feet of tunnel	0.00	632,727.44
Contract No. 14, Constructon of East Portion of Wachusett-Coldbrook Tunnel and Shaft 1	10,000.02	3,515,787.08
Contract No. 17, Construction of West Portion of Wachusett-Coldbrook Tunnel and Shaft 8	0.00	4,127,094.19

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
Contract No. 18, Furnishing Iron Castings for the Ware River Intake Works	$0.00	$19,431.07
Contract No. 19, Construction of Dam and Substructure of Intake Building for the Ware River Intake Works	0.00	285,580.49
Contract No. 22, Furnishing and Installing an Unwatering Pump in Shaft 1	2,037.33	13,371.76
Contract No. 24, Construction of Superstructure of Intake Building for the Ware River Intake Works	7,263.08	70,114.04
Contract No. 25, Construction of Superstructure of Outlet Building at Shaft 1	8,048.30	62,329.23
Contract No. 26, Furnishing and Installing Power and Lighting Wiring and Electrical Equipment at the Outlet Works at Shaft 1	1,785.45	10,685.21
Contract No. 28, Grading the Grounds at the Ware River Intake Building	3,625.71	8,164.14
Contract No. 29, Grading the Grounds at the Outlet Building at Shaft 1	3,393.81	11,852.68
Contract No. 31, Construction of the Superstructure of the Head House at Shaft 4	3,241.47	5,689.02
Total Contracts	$39,395.17	$9,629,739.99
Permanent Construction — Except Construction Contracts:		
Installed Equipment	$738.33	$60,304.23
Temporary Equipment	0.00	5,013.60
Labor	1,043.60	2,138.35
Contracts for Equipment for Surveys	0.00	898.34
Maintenance of Partially Completed Structures	2,104.01	5,009.99
Maintenance of Grounds	2,031.51	2,031.51
Purchase of Plants, Trees and Shrubbery	614.63	614.63
Rental of Equipment	0.00	7.00
Miscellaneous Expense	197.83	9,436.21
Total	$6,729.91	$85,453.86
Total Wachusett-Coldbrook Tunnel Ware Supply	$209,118.35	$11,427,819.80
Special Investigation — Pollution of Ware and Quinapoxet Watersheds. (Expenditures under Chapter 66, Acts of 1931)		
Salaries, Engineering	$0.00	$986.67
Miscellaneous Expense	0.00	1,009.32
Total Special Investigation	$0.00	$1,995.99
Coldbrook–Swift Tunnel Section of Quabbin Aqueduct		
General Overhead:		
Administration	$2,307.22	$13,177.95
Engineering	9,510.26	56,052.86
Total General Overhead	$11,817.48	$69,230.81
Engineering:		
Salaries, Engineering and Clerical	$47,768.58	$106,581.20
Labor	212.20	284.45
Furniture and Fixtures	13.97	665.31
Engineering Instruments	240.74	4,211.45
Rent and Upkeep	1,396.32	6,559.82

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
Automobile Purchase	$985.00	$7,427.97
Automobile Maintenance	1,415.49	11,851.86
Contracts for Investigations and Surveys	0.00	13,525.66
Materials of Construction	0.00	2.25
Miscellaneous Expense (undistributed)	825.05	5,803.70
Printing and Blueprinting	52.56	486.03
Stationery and Office Supplies	221.02	1,595.37
Postage	48.99	269.29
Total Engineering	$53,179.92	$159,264.36
REAL ESTATE:		
Legal and Expert Expense	$116.19	$2,890.47
Labor	3.20	12.20
Miscellaneous Expense (undistributed)	0.00	27.16
Printing and Blueprinting	0.14	34.87
Postage	0.00	5.68
Purchases and Settlements	4,610.00	18,025.00
Taxes	106.15	128.65
Maintenance of Real Estate	0.00	9.25
Fire Protection, Equipment	0.00	60.86
Total Real Estate	$4,835.68	$21,194.14
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 20, Construction of Coldbrook-Swift Tunnel	$1,937,314.60	$2,240,471.82
Total Contracts	$1,937,314.60	$2,240,471.82
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$0.00	$64.75
Installed Equipment	0.00	91.87
Miscellaneous Expense	140.06	233.44
Total	$140.06	$390.06
Total Coldbrook-Swift Tunnel	$2,007,287.74	$2,490,551.19
QUABBIN RESERVOIR, SWIFT SUPPLY		
GENERAL OVERHEAD:		
Administration	$10,763.44	$69,992.93
Engineering	43,020.41	406,745.19
Total General Overhead	$53,783.85	$476,738.12
ENGINEERING:		
Salaries, Engineering and Clerical	$10,782.51	$271,716.09
Labor	1,377.20	4,460.79
Furniture and Fixtures	77.49	2,940.97
Laboratory Equipment	48.24	258.94
Laboratory Supplies	306.14	306.14
Rental of Equipment	16.25	16.75
Engineering Instruments	470.97	6,167.24
Rent and Upkeep	991.97	4,055.64
Automobile Purchase	540.00	12,646.10
Automobile Maintenance	609.42	11,073.20
Special Experiments	0.00	392.40
Contracts for Investigations and Surveys	–997.69 [1]	10,594.79
Office Buildings	0.00	4,835.91
Miscellaneous Expense (undistributed)	478.28	3,736.47
Printing and Blueprinting	264.77	1,218.21
Stationery and Office Supplies	531.87	3,928.11
Postage	127.39	514.39
Total Engineering	$15,624.81	$338,862.14

[1] Expenditure previously carried in this account but chargeable in its entirety to the Main Dam and Dike has been transferred to the proper account.

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
Real Estate:		
Legal and Expert Expense	$10,412.29	$118,431.82
Labor	4.00	71.35
Furniture and Fixtures	0.00	15.68
Miscellaneous Expense (undistributed)	1,026.49	3,899.48
Advertising	0.00	208.66
Printing and Blueprinting	151.04	706.22
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	399,744.82	5,082,251.98
Taxes	36,872.47	124,903.17
Maintenance of Real Estate	806.19	1,555.53
Water Supply Systems	16.00	16.00
Fire Protection, Equipment	96.89	3,435.86
Automobile Purchase	0.00	771.69
Automobile Maintenance	3.80	222.85
Labor	6.00	6.00
Miscellaneous Expense	16.43	92.42
Police Protection, Labor	0.00	10.00
Special Agents, Salaries	2,460.00	11,001.33
Equipment	0.00	118.33
Automobile Purchase	319.00	1,236.96
Automobile Maintenance	354.89	2,017.06
Miscellaneous Expense (undistributed)	165.25	799.09
Printing and Blueprinting	0.00	41.60
Stationery and Office Supplies	1.53	8.32
Postage	2.90	10.32
Renting Agents, Salaries	2,820.00	12,835.43
Furniture and Fixtures	0.00	29.29
Miscellaneous Expense (undistributed)	86.80	386.02
Stationery and Office Supplies	7.29	16.08
Postage	22.29	22.29
Payments to Towns	0.00	6,000.00
Total Real Estate	$455,396.37	$5,371,121.28
Quabbin Reservoir Damages:		
Salaries, Engineering	$0.00	$48.68
Legal and Expert Expense	931.00	931.00
Consultant Expense	0.00	1,443.37
Miscellaneous Expense	9.55	12.25
Purchases and Settlements	29,720.00	43,860.00
Total Quabbin Reservoir Damages	$30,660.55	$46,295.30
Swift Diversion Damages:		
Salaries, Engineering and Clerical	$19,070.54	$43,519.61
Legal and Expert Expense	2,156.12	3,308.12
Consultant Expense	20,684.18	27,102.75
Labor	28.80	73.70
Laboratory Equipment	39.39	577.35
Laboratory Supplies	279.52	300.50
Engineering Instruments	0.00	561.03
Rental of Equipment	0.00	9.00
Automobile Maintenance	263.17	306.79
Contracts for Investigations and Surveys	0.00	569.47
Materials of Construction	0.00	18.99
Miscellaneous Expense (undistributed)	716.96	4,984.58
Printing and Blueprinting	268.64	385.90
Purchases and Settlements	0.00	202,500.00
Total Swift Diversion Damages	$43,507.32	$284,217.79

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
QUABBIN RESERVOIR — CEMETERIES*		
QUABBIN PARK CEMETERY CONSTRUCTION:		
Salaries, Engineering and Clerical	$5,379.48	$10,364.44
Legal and Expert Expense	–3.75	65.00
Consultant Expense	125.00	125.00
(Construction) Labor	2,513.77	7,381.53
Tools and Equipment	82.33	82.33
Automobile Purchase	–2,214.63	1,615.37
Automobile Maintenance	326.59	533.42
Rental of Equipment	23.19	33.19
Purchases and Settlements	206.90	4,850.00
Construction Materials	–1,197.42	1,322.63
Purchase and Planting of Trees and Shrubbery	155.60	155.60
Receiving Vault	2,768.85	2,768.85
Water Supply System	1,249.97	1,249.97
Maintenance of Grounds	1,069.70	1,069.70
Transportation of Bodies	–45.00	0.00
Transportation of Monuments	–840.50	0.00
Monuments Including Inscriptions	–252.25	0.00
Miscellaneous Expense (undistributed)	52.83	139.04
Printing, Blueprinting, etc.	150.41	150.41
Stationery and Office Supplies	0.00	3.51
Contract 34, Construction of Driveways	5,472.41	7,842.94
Sub Total Quabbin Park Cemetery Construction	$15,023.48	$39,752.93
REMOVALS FROM CEMETERIES WITHIN RESERVOIR AREA TO QUABBIN PARK CEMETERY:		
Salaries, Engineering and Clerical	$169.55	$169.55
Tools and Equipment	264.26	264.26
Automobile Purchase	2,669.99	2,669.99
Automobile Maintenance	1.45	1.45
Removal and reinterment of bodies	538.69	538.69
Removal and resetting of monuments	164.40	164.40
Miscellaneous Expense	2.00	2.00
Sub Total Removals to Quabbin Park Cemetery	$3,810.34	$3,810.34
REMOVALS FROM CEMETERIES WITHIN RESERVOIR AREA TO CEMETERIES OTHER THAN QUABBIN PARK:		
Salaries, Engineering and Clerical	$4,895.36	$4,895.36
Automobile Purchase	380.00	380.00
Automobile Maintenance	14.80	14.80
Purchases and Settlements	5,659.60	5,659.60
Perpetual Care Fund Contributions	100.00	100.00
Removal and Reinterment of Bodies	5,234.95	5,234.95
Removal and Resetting of Monuments	4,659.19	4,659.19
Miscellaneous Expense	117.91	117.91
Sub Total Removals to Other Cemeteries	$21,061.81	$21,061.81
Total Quabbin Reservoir Cemeteries	$39,895.63	$64,625.08
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$214.78
Total	$0.00	$214.78

*New accounts have been opened during the year to show separately and in greater detail the costs of Quabbin Park Cemetery and of removals of bodies, thus necessitating transfers from many of the old accounts to new accounts.

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
HIGHWAY AND PUBLIC UTILITY RELOCATION:		
Salaries, Engineering and Clerical	$42,458.34	$48,470.59
Legal and Expert Expense	9.00	49.10
Labor	153.20	241.70
Contract No. 21, Construction of about 5.2 miles of the Ware-Belchertown Highway	76,799.84	124,980.25
Installed Equipment	97.82	97.82
Temporary Equipment	149.50	149.50
Engineering Instruments	166.77	166.77
Automobile Purchase	535.00	535.00
Automobile Maintenance	1,010.72	1,050.47
Miscellaneous Expense (undistributed)	543.17	576.66
Printing and Blueprinting	2.71	19.39
Stationery and Office Supplies	59.57	59.57
Total	$121,985.64	$176,396.82
Total Quabbin Reservoir, Swift Supply	$760,854.17	$6,758,471.31
QUABBIN RESERVOIR — MAIN DAM AND DIKE		
GENERAL OVERHEAD:		
Administration	$11,425.26	$16,522.61
Engineering	45,664.48	65,415.95
Total General Overhead	$57,089.74	$81,938.56
ENGINEERING:		
Salaries, Engineering and Clerical	$39,287.51	$63,990.38
Consultant Expense	6,258.67	7,571.22
Labor	839.30	1,007.40
Furniture and Fixtures	0.00	64.18
Laboratory Equipment	193.57	759.77
Rental of Equipment	430.50	430.50
Engineering Instruments	145.82	145.82
Rent and Upkeep	16.00	16.00
Automobile Maintenance	513.35	560.63
Contracts for Investigations and Surveys	11,211.95	49,984.46
Miscellaneous Expense (undistributed)	1,080.75	1,900.95
Printing and Blueprinting	376.62	376.62
Stationery and Office Supplies	80.27	145.05
Total Engineering	$60,434.31	$126,952.98
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 30, Constructing Stream Control Works at Main Dam	$364,973.98	$424,335.73
Contract No. 32 Constructing Exploratory Caissons at Main Dam and Dike	151,590.58	162,838.33
Total Contracts	$516,564.56	$587,174.06
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$2,519.40	$2,519.40
Installed Equipment	3,253.00	3,253.00
Temporary Equipment	1,549.81	1,549.81
Miscellaneous Expense	1,093.01	1,096.01
Total	$8,415.22	$8,418.22
Total Quabbin Reservoir — Main Dam and Dike	$642,503.83	$804,483.82

Southern Sudbury Emergency Supply

	Year ending Nov. 30, 1932	Total to Nov. 30, 1932
General Overhead	$0.00	$42,098.25
Engineering	0.00	44,235.07
Real Estate:		
Legal and Expert Expense	7.78	2,221.60
Consultant Expense	0.00	116.87
Printing and Blueprinting	0.00	4.28
Purchases and Settlements	0.00	27,763.22
Taxes	138.81	392.60
Total Real Estate	$146.59	$30,498.57
Southern Sudbury Diversion Damages	0.00	50,752.66
Permanent Construction – Construction Contracts (except No. 5)	0.00	375,194.44
Contract No. 5, Cordaville Pipe Line	0.00	83,262.86
Permanent Construction — Except Construction Contracts	0.00	11,937.37
Total Southern Sudbury Emergency Supply	$146.59	$637,979.22

Summary

Wachusett-Coldbrook Tunnel, Ware Supply	$209,118.35	$11,427,819.80
Special Investigation — Pollution of Ware and Quinapoxet Watersheds	0.00	1,995.99
Coldbrook-Swift Tunnel	2,007,287.74	2,490,551.19
Quabbin Reservoir, Swift Supply	760,854.17	6,758,471.31
Main Dam and Dike	642,503.83	804,483.82
Southern Sudbury Emergency Supply	146.59	637,979.22
Unassigned	–38.79	604.72
Grand Total	$3,619,871.89	$22,121,906.05

Receipts from Rents, Sales, etc.

Receipts from Sales	$18,060.16	$108,324.49
Receipts from Rents	51,293.42	204,407.20
Miscellaneous Receipts	567.85	2,919.99
Total Receipts	$69,921.43	$315,651.68

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE QUABBIN RESERVOIR

(TITLE VESTED IN COMMONWEALTH)

TOWNS	TOTAL – NOV. 30, 1931.		TOTAL FOR YEAR ENDING NOV. 30, 1932 (ACRES)	TOTAL NOV. 30, 1932 (ACRES)	REMARKS
	1931 ANNUAL REPORT (ACRES)	REVISED-SEE NOTE (ACRES)*			
BELCHERTOWN	1,653	1,575	88	1,663	
DANA	6,871	6,808	679	7,487	
ENFIELD	6,410	6,542	515	7,057	* Revisions have been made using acreages obtained from surveys wherever available otherwise from deeds, property blanks etc.
GREENWICH	8,401	8,791	744	9,535	
HARDWICK	2,224	2,130	103	2,233	
NEW SALEM	5,425	5,539	779	6,318	
PELHAM	2,095	2,102	589	2,691	
PETERSHAM	961	761	–	761	
PRESCOTT	8,619	8,798	185	8,983	
SHUTESBURY	1,490	1,473	45	1,518	
WARE	426	425	35	460	
WENDELL	37	36	–	36	
TOTALS	44,612	44,980	3,762	48,742	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TAKINGS OF REAL ESTATE (AND WATER RIGHTS)

TAKING FOR	TAKING NO.	TOWN	COUNTY	DATE OF TAKING	PLAN NO.	TITLE VESTED IN COMMONWEALTH FEE (Acres)	EASEMENT (Acres)
Southern Sudbury Emergency Supply.	1 to 9 inc	Details previously reported in 1930			C-1 to C-15 incl.	258.81 (Also Water Rights)	29.02
Wachusett-Coldbrook Tunnel.	1 to 4 inc	Details previously reported in 1930			T-1 to T-13 incl.	570.22	
Coldbrook-Swift Tunnel.	1 to 3 inc	Details previously reported in 1931 *(391.42 acres of this total are within the Swift River Res. Area)			T-14 to T-27 incl.	*544.81	4.06
Swift River Reservoir	1 to 3 inc	Details previously reported in 1931			S-1 to S-7 incl.	205.84	0.39
" " "	4	Ware	Hampshire	Aug. 16, 1932	S-8	47.76	
" " "	5	Enfield	Hampshire	Nov. 1, 1932	S-9	174.40	
		Greenwich	Hampshire			2.00	
		Ware	Hampshire			1.90	
						431.90	
Ware River Watershed,-School.	1	Oakham	Worcester		W-1	0.25	
" " Taking of Flood Waters of the Ware River and its Tributaries above Diversion Dam at Coldbrook in Barre.		Barre	Worcester		No Plan	Water Rights	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED BETWEEN NOV. 30, 1930 AND NOV. 30, 1932

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
10.	Transmission Line for Construction of Wachusett-Coldbrook Tunnel.	Tunnel Line	Ware	New England Power Company	Date of Agreement=April 27, 1927			Maint. at Cost. Constr. at Cost.	# 33,107.81 86,439.58	June 10, 1931
14.	East Portion of Wachusett-Coldbrook Tunnel.	West Boylston, Holden and Rutland.	Ware	West Construction Co. Assignee	Nov. 18, 1927	13	April 30, 1928	4,074,981.25 *	3,515,787.08	July 28, 1931
17.	West Portion of Wachusett-Coldbrook Tunnel.	Rutland, Oakham and Barre.	Ware	West Construction Co. Assignee	Nov. 18, 1927	12	April 30, 1928	4,799,362.50 **	4,127,094.19	May 15, 1931
19.	Dam and Substructure of Intake Building.	Barre.	Ware	J. W. Bishop Co.	July 16, 1929	7	July 23, 1929	273,077.00	285,580.49	Mar. 9, 1931
21.	Portion of the Ware Belchertown Highway	Ware and Belchertown.	Swift	The Lane Construction Corporation	July 17, 1931	17	July 17, 1931	208,381.50	+ 225,707.19	Oct. 11, 1932
22.	Unwatering Pump at Shaft 1.	West Boylston.	Ware	F. A. Mazzur Co., Inc.	Nov. 5, 1929	3	Nov. 12, 1929	11,975.00	13,371.76	Feb. 13, 1932
24.	Superstructure of Ware River Intake Building.	Barre.	Ware	Munroe & Wescott Inc.	July 22, 1930	10	July 22, 1930	69,669.00	70,114.04	Jan. 6, 1932
25.	Superstructure of Outlet Works at Shaft 1.	West Boylston	Ware	Munroe & Wescott Inc.	July 22, 1930	10	July 22, 1930	61,363.00	62,329.23	Jan. 6, 1932
26.	Wiring and Electrical Equipment Outlet Works Shaft 1.	West Boylston	Ware	Anderson-Coffey Co. Inc.	Sept. 23, 1930	8	Sept. 23, 1930	8,850.00	10,685.21	Feb. 3, 1932
27.	Earth Fill along Ware River.	Barre	Ware	Raymond A. Bergesson	Sept. 23, 1930	14	Sept. 23, 1930	4,050.00	4,395.51	Dec. 20, 1930
28.	Grading Grounds of Ware River Intake Building.	Barre	Ware	Anthony Ross & Son	Aug. 14, 1931	16	Aug. 14, 1931	6,571.75	8,164.14	Aug. 6, 1932
29.	Grading Grounds of Wachusett Outlet Building.	West Boylston	Ware	Anthony Ross & Son	Aug. 14, 1931	17	Aug. 14, 1931	9,998.05	11,852.68	Aug. 6, 1932
31.	Head House at Shaft 4.	Rutland	Ware	E. D. Ward Co.	Aug. 25, 1931	8	Aug. 25, 1931	5,439.00	5,689.02	Jan. 6, 1932
32.	Exploratory Caissons at Main Dam and Dike of Quabbin Reservoir.	Enfield and Ware	Swift	Dravo Contracting Co.	Sept. 8, 1931	10	Sept. 8, 1931	(A) 115,900.00 (B) 133,825.00	162,838.33	Sept. 20, 1932
34.	Driveways in Quabbin Park Cemetery.	Ware	Swift	The Lane Construction Corporation.	Oct. 20, 1931	16	Oct. 27, 1931	4,967.50	7,842.94	Aug. 8, 1932

Awarded to lowest bidder in each case.

Note:- For contracts completed prior to Nov. 30, 1930 - See the 1931 Annual Report.
+ Of this amount the State Dep't. of Public Works paid $95,726.94.
* Portion of work completed under Contract 12 before Contract 14 was executed reduces this amount by about 7%.
** " " " " " Contracts 4 & 8 " " 17 " " " " " " " ".

(A)=Assuming caissons to be sunk mostly by open dredging.
(B)= " " " " " " under pressure.

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS IN FORCE ON NOV. 30, 1932

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	DATE AWARDED	BASIS OF AWARD	PAYMENTS TO DATE
20.	Coldbrook-Swift Tunnel.	Barre, Hardwick and Greenwich.	Swift	Wenzel & Henoch, Construction Co.	Mar. 27, 1931	13	April 10, 1931	$4,978,031.80	$2,240,471.82
23.	Making Borings.	Belchertown, Ware, Enfield, Greenwich & Hardwick.	Swift	Sprague & Henwood Inc.	Nov. 5, 1929	6	Nov. 5, 1929	10,950.00	27,695.92
30.	Stream Control Works at Main Dam Quabbin Reservoir.	Belchertown, Enfield and Ware.	Swift	Northern States Contracting Co.	July 17, 1931	19	July 21, 1931	560,922.50	424,335.73
33.	Purchase of Power at Shaft 1.	West Boylston	Ware	New England Power Co.	Date of Agreement = Aug. 6, 1931			Agreed Rates	1,425.03
35.	Purchase of Power at Dam Site.	Enfield	Swift	New England Power Co.	Date of Agreement = June 2, 1932			Agreed Rates	453.50
37.	Purchase of Power at Dike Site.	Enfield	Swift	New England Power Co.	Date of Agreement = Sept. 21, 1932			Agreed Rates	None

Awarded to lowest bidder in each case.

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of 1926, respectfully presents for the year ending November 30, 1933, its

EIGHTH ANNUAL REPORT

I. Organization and Administration

Davis B. Keniston continued during the year as Chariman of the Commission, and Charles M. Davenport and Thomas D. Lavelle, both of Boston, as Associate Commissioners. R. Nelson Molt continued as Secretary.

The clerical force of the Commission's office at Boston remained substantially the same throughout the year. Three special agents under the direction of the Commission continued to care for the property acquired by the Commission in the Swift River and Ware River areas. Real estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 148 employees during the year. The maximum number employed at any one time by contractors on the various construction projects during the year was 886 persons.

The Commission continued, through duly appointed agents, the direction of the town government of the Town of Prescott, as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

II. Engineering Department

Frank E. Winsor continued as Chief Engineer, Karl R. Kennison as Designing Engineer, and Walton H. Sears as Mechanical Engineer.

The field divisions were continued in charge of three division engineers as follows: Wachusett-Coldbrook Tunnel Division, William W. Peabody; Coldbrook-Swift Tunnel Division, Richard R. Bradbury; Quabbin Reservoir Division, N. LeRoy Hammond.

The Commission retained the services of X. H. Goodnough, Inc., and of J. Waldo Smith, formerly Chief Engineer of the New York Board of Water Supply, as consulting engineers until the death of the latter on October 14.

By the death of Mr. Smith the Commission lost one of its ablest counsellors. Born and reared in Massachusetts, after graduating from the Massachusetts Institute of Technology and following early experience in this state, he became chief engineer of large water supplies in Eastern New Jersey. In the year 1903 he became chief engineer on the Croton water supply of the city of New York, and two years later chief engineer on the Catskill water works for that city. For thirty years he guided the development of New York's water supply as chief engineer and consulting engineer, and was frequently called upon for advice elsewhere. He served as consultant in early investigations for the new water supply of the Metropolitan District, and had served the Commission since its creation in 1926.

Charles T. Main, of Charles T. Main, Inc., of Boston, was employed from time to time as a general consultant on mill and water power damages and also on the design of the dam and dike of Quabbin Reservoir. Dr. Charles P. Berkey of Columbia University continued as consulting geologist. Other consultants were employed from time to time as needed.

III. Offices

The office of the Commission and of the Chief Engineer continued on the ninth floor of the Metropolitan District Commission Building at 20 Somerset Street, Boston. The division offices for the Wachusett-Coldbrook Tunnel section and of

the Coldbrook-Swift Tunnel section of the Quabbin Aqueduct and of the Quabbin Reservoir area continued at Holden, Hardwick and Enfield, respectively. The laboratories for water analysis and soil testing were continued at Enfield.

IV. Real Estate and Water Rights

The Commission, for reservoir purposes, has acquired (or has under option) a total of 56,038 acres of land in the Swift River watershed, and for sanitary protection and construction purposes in the Ware River watershed a total of 5,547 acres.

The Commission acquired by eminent domain 173.51 acres in fee, and easements in 6.86 acres of land in the towns of Belchertown, Pelham, Shutesbury, New Salem and Orange for road construction, and easements in 22.94 acres of land in the towns of Rutland and Holden for the construction of a trunk sewer for the disposal of sewage from the Ware, Quinapoxet and Wachusett watersheds.

Under the provisions of Section 5 Chapter 321 of 1927, the Supreme Court appointed, on April 5, 1933, as a Board of Referees, Thomas R. Hickey, Esq., of Easthampton, Nathan P. Avery, Esq., of Holyoke and Robert W. King, Esq., of Springfield. Mr. Hickey died June 14 and James M. Healy, Esq., of Springfield, was appointed to fill the vacancy.

The Commission has, during the year, concluded settlements with two owners of water privileges on the Ware River for the diversion of the waters of the Ware River and with four owners of water privileges on the Chicopee River for all claims for present and future damages caused by the diversion of the Ware and Swift rivers.

V. Southern Sudbury Supply

All work upon the Southern Sudbury Supply having been completed, the works and all other property incidental thereto were, on April 18, turned over to the Metropolitan District Commission for maintenance and operation.

VI. Ware River Supppy

The Commission purchased some additional properties for protection of the watershed of the Ware River including the property in Rutland under the control of the Department of Correction, comprising the Massachusetts Prison Camp and Hospital, and in conjunction with the Department of Public Health has continued its studies of possible sources of pollution from that watershed and the best methods for their elimination.

Under the provisions of Chapter 262 of the Acts of 1932, the Commission concluded an agreement with the City of Worcester for the disposal of sewage to be diverted from the watersheds of the Ware and Quinapoxet rivers and the watershed of Wachusett Reservoir into the sewerage system of the city. The Commission subsequently authorized the construction of a trunk sewer from the Rutland State Sanatorium and the U. S. Veterans' Hospital in the neighborhood of Rutland Center through Rutland and through or near the villages of Eagleville and Holden Center in the town of Holden to a point at the boundary line between Holden and Worcester to connect with a sewer line of the city of Worcester to be built and maintained by the city under this agreement with the Commission from that point to its existing system. Contract No. 39 was awarded on July 11 to James J. Coughlan & Sons, Inc., of Boston, for constructing the sewer in Rutland and Holden. The two temporary chlorinating plants installed at points in the upper watershed of the Ware River were maintained in readiness for operation.

No water was diverted during the year from the Ware River.

VII. Swift River Supply

Real estate and topographic surveys were continued during the year.

The Wenzel & Henoch Construction Company continued under Contract No. 20 for the construction of the Coldbrook-Swift section of the Quabbin Aqueduct. The rock excavation has been completed and about 45% of the 10.4 miles of the tunnel included in this contract has been lined with concrete.

Contract No. 30 which was awarded in July, 1931, to the Northern States Contracting Company, for constructing the river diversion tunnel at the site of the main dam of Quabbin Reservoir, was completed on July 1.

Contract No. 36 was awarded on December 28, 1932, to the West Construction Company, the contractor who had successfully completed 13 miles of the Wachusett-Coldbrook section of Quabbin Aqueduct, for constructing a core wall to sound rock at the site of the dike of Quabbin Reservoir in the towns of Enfield and Ware. Work has been in progress under this contract, the open trench across the Valley 40 feet below the level of Beaver Brook being completed and the caisson or core wall substantially completed. There are in all 31 caissons across the Valley and 17 on the easterly end of the dike have been sunk to bed rock and sealed. The remaining 14 caissons on the westerly end have been placed and are partially down to bed rock.

The Commission arranged with the New England Power Company and the Central Massachusetts Electric Company to remove and relocate the power transmission lines extending across Quabbin Reservoir site. These relocations were economical at this time since owing to decreased demands for power it was possible to discontinue these lines temporarily and use the towers and other equipment upon the new locations. The relocations to the south and to the west of the reservoir are substantially completed.

Three contracts were awarded for the construction of a highway west of the reservoir site about twenty-one miles long from Belchertown to a point just beyond the road between North Dana and Orange. The road starts at Belchertown-Amherst highway about one-half mile north of Belchertown Center and passes through Pelham Center, the Village of Cooleyville and just westerly of the Village of New Salem to a point just beyond the Orange-North Dana Road.

The location for this new road was approved by the County Commissioners of Franklin and Hampshire Counties and by the Department of Public Works and is being built in cooperation with the Department of Public Works and when completed will be taken over and operated by that Department as a state highway.

Contract No. 41 for the southerly portion of this road, about 9.1 miles in length, and extending from the road leading from Belchertown Center to Amherst through Pelham Center, was awarded to Carlo Bianchi and Company, Inc., of Framingham, Mass., on July 19. Contract No. 43 for the central portion of 7.6 miles extending from about ½ mile beyond Pelham Center through the village of Cooleyville and ending just north of New Salem Center was awarded to V. Barletta Company of Roslindale, Mass., on August 22. Contract No. 44 for the last and northerly portion of the highway, about 4.1 miles in length, extending from a point north of New Salem Center to and across the North Dana-Orange State highway, was awarded on November 14 to John Iafolla Construction Company of Dedham, Mass.

VIII. Cemeteries

The Commission has continued the assignment of lots in the new Quabbin Park Cemetery and 659 bodies were removed from the Quabbin Reservoir area during the year of which 589 have been interred in Quabbin Park Cemetery. There have also been a total of 30 original burials made in the Cemetery. To date a total of 1,419 bodies have been removed from the Quabbin Reservoir area.

IX. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

X. Other Reports

The report of the Chief Engineer is herewith presented.

Respectfully submitted,

DAVIS B. KENISTON, *Chairman.*
CHARLES M. DAVENPORT, *Associate Commissioner.*
THOMAS D. LAVELLE, *Associate Commissioner.*

20 Somerset Street, Boston, Mass.
January 15, 1934.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN: — The following is a report of the engineering department for the year ending November 30, 1933.

ORGANIZATION

It has been necessary to increase the engineering organization about 20% during the year to handle the new and additional construction.

Karl R. Kennison, Designing Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, preparation of contract specifications, contract and working drawings. He also continued as principal assistant to the Chief Engineer.

Charles L. Coburn and Stanley M. Dore, Assistant Designing Engineers, continued their general supervision of the detailed work of the office; and Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. They have assisted in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Quabbin Reservoir Division.

X. Henry Goodnough, Inc., and J. Waldo Smith, until his death October 14, continued as consulting engineers. Charles T. Main, consulting engineer of Boston, Dr. Charles P. Berkey, geologist of Columbia University, Arthur A. Shurcliff, landscape architect of Boston, and other experts were employed from time to time.

The assignment of employees under the direction of the Chief Engineer at the end of the year and of the preceding year was as follows:

	Nov. 30, 1932	Nov. 30, 1933
Headquarters Office, Designing Division	36	38
Holden Office, Wachusett-Coldbrook Tunnel Division	22	26
Hardwick Office, Coldbrook-Swift Tunnel Division	30	40
Enfield Office, Quabbin Reservoir Division	47	61
Total Engineering Force	135	165

The maximum force during the year was 165, during the six weeks ending November 25. The minimum force was 134, during the three weeks ending January 28. The average force for the year was 148.

OFFICES

The office of the Chief Engineer and Designing Division was continued in the Metropolitan District Commission Building at 20 Somerset Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Quabbin Reservoir Division was continued in the property of the Commonwealth formerly known as the Frances W. Chandler house on Quabbin Road, and the laboratories for water analysis and for soil testing were continued in the property of the Commonwealth formerly known as the Barlow house, in Enfield.

HEADQUARTERS OFFICE

Summary of the Year's Work

Real Estate. — Reports and recommendations with respect to the purchase of real estate in the Quabbin Reservoir area were submitted to the Commission during the year covering 4,370 acres, making a total reported on to date of 71,010 acres.

PROGRESS OF REAL ESTATE NEGOTIATIONS FOR QUABBIN RESERVOIR

	Total Area Negotiated Including Owners' Offers to Sell to Commonwealth (Acres)	Area not Required (Acres)	Title Vested in Commonwealth (Acres)
Total for Year ending Nov. 30, 1933	4,370	403	5,632*
Total to Nov. 30, 1932	66,640	6,792	48,675
Total to Nov. 30, 1933	71,010	7,195	54,307

Options outstanding Nov. 30, 1933, include 1,731 acres.
* Includes some offered in previous years.

Reports and recommendations were also made with respect to the purchase of real estate for sanitary protection in the Ware River watershed above the intake works at Coldbrook.

PROGRESS OF REAL ESTATE PURCHASES FOR WARE RIVER WATERSHED PROTECTION

	Title Vested in Commonwealth (Acres)
Total for year ending Nov. 30, 1933	1,192
Total to Nov. 30, 1932	4,067
Total to Nov. 30, 1933	5,259

Options outstanding Nov. 30, 1933, include 288 acres.

Real estate taking plans were prepared and filed during the year as shown in the appended table.

Contracts and Specifications. — Contract 36, for constructing a core wall to sound rock at the site of the dike, so-called, of Quabbin Reservoir in the towns of Enfield and Ware, was executed December 28, 1932.

Plans and specifications were prepared for Contract 39, for constructing a trunk sewer in the towns of Rutland and Holden, for the purpose of maintaining and protecting the purity of the water supplied from the Wachusett, Quinapoxet and Ware river areas as authorized by Chapter 262 of the Acts of 1932. The contract was executed July 11.

Plans and specifications were prepared for Contract 40, for the removal, and relocation outside the flow line of Quabbin Reservoir, of the transmission and telephone lines and substation of the New England Power Company and the Central Massachusetts Electric Company in the towns of Belchertown, Enfield and Ware, and for the alteration of transmission line towers at points where the reservoir will be spanned by the lines of these companies in the town of New Salem. The contract was executed June 20.

Plans and specifications were prepared for Contract 41, for constructing, in substitution for highways in the Quabbin Reservoir area, a portion of the Belchertown-Pelham highway in the towns of Belchertown and Pelham. The contract was executed July 20.

Contract 42 was prepared, being an agreement with the city of Worcester as to compensation for the construction by the City of a connecting link between the Rutland-Holden sewer, being constructed under Contract 39 and the city's trunk sewerage system, and for the right to use this system and the city's treatment plant. The contract was executed May 1.

Plans and specifications were prepared for Contract 43, for constructing an extension of the Belchertown-Pelham highway to New Salem Center in the towns of Shutesbury and New Salem. The contract was executed August 25.

Plans and specifications were prepared for Contract 44, for constructing an extension of the Belchertown-Pelham highway north of New Salem Center in the towns of New Salem and Orange. The contract was executed November 15.

Working drawings for Contracts 20, 30, 36 and 39 were prepared and issued.

Work was in progress on the preparation of plans and specifications for constructing a core wall to sound rock at the site of the main dam of Quabbin Reservoir in the towns of Enfield, Belchertown and Ware similar to that being constructed under Contract 36 at the site of the dike.

Inspection and Tests. — E. L. Conwell and Company continued the testing of cement. The Worcester Polytechnic Laboratory continued the testing of concrete cylinders and steel reinforcement bars. William R. Conard of Burlington, N. J., inspected cast-iron pipe furnished for the Rutland-Holden sewer under Contract 39.

The inspection of weir castings purchased by the Commission for installation in the sewage measuring stations under Contract 39 and of special castings for stop log grooves for Contract 20 was made by the engineering force. These measuring weirs were rated by tests made in the Hydraulic Laboratory of the Massachusetts Institute of Technology in Cambridge. The engineering force cooperated with the laboratory personnel in making these tests.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey.

The gaging station on the Chicopee River at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and the

United States Geological Survey, and further discharge measurements were made from time to time to define the rating curve more exactly.

The gaging station on the Chicopee River at the Red Bridge plant of the Ludlow Manufacturing Associates was continued in cooperation with that company and further discharge measurements were made from time to time to define the rating curve more exactly.

The gaging station on the Swift River at Bondsville was continued in cooperation with the Otis Company.

Cooperation with the United States Geological Survey in the operation and maintenance of the gaging station on the Connecticut River at Thompsonville, Connecticut, was continued.

In connection with the examination of the waters of the Ware, Swift and Chicopee rivers, observations of flow were continued from time to time and additional temporary gaging stations established as required and data for the use of consultants and experts were prepared.

Southern Sudbury Emergency Supply

Record plans of the Southern Sudbury Emergency Supply were completed, and on April 18 the works and all property incidental thereto were turned over by the Commission to the Metropolitan District Commission. These works consist of (1) a 24-inch gravity flow pipe line from Ashland Reservoir of the District to the gate house at Framingham Reservoir No. 2, (2) a 20-inch gravity flow pipe line from Whitehall Reservoir of the District to a point on City Brook where this brook is diverted by a small diversion dam, reservoir and open channel into Hopkinton Reservoir of the District and (3) a 30-inch gravity flow pipe line from Hopkinton Reservoir across the Sudbury River near Cordaville and into the main Sudbury Reservoir; also a pumping station and a branch line from an intake on the Sudbury River at Cordaville.

Ware River Diversion

There was no diversion of Ware River water into Wachusett Reservoir. In the period June 15 to October 15, inclusive, in conformity with the requirements of the War Department, no water was diverted. At other times, the daily flow in the river was frequently sufficient to permit diversion, but no diversion was made because of the present inadequacy of storage capacity in the reservoir of the District.

On January 24 the east tunnel heading from Shaft 9 holed through into the west end of the Wachusett-Coldbrook Tunnel, and the gates in the steel bulkhead about 2,200 feet west of Shaft 8 were closed to prevent leakage past the bulkhead from the operations under Contract 20 and to allow diversions to be made from the Ware River into Wachusett Reservoir without danger of flooding west of the bulkhead. On November 17 an inspection was made of about 7 miles of the Wachusett-Coldbrook Tunnel extending from Shaft 8 easterly to a point between Shafts 4 and 5. On these occasions the intake shaft, the steel bulkhead and the tunnel were found to be in excellent condition.

Design of Structures

Shaft 9. — Designs were continued for an emergency spillway and vent and a head house at the top of Shaft 9.

Shaft 12. — Swift River Intake. — Studies were continued of the high level intake and requirements of a head house and a service building. Studies were made of grading at the intake and of a relocation of the existing highway to an elevation about 5 feet above the reservoir flow line opposite the shaft so that the extension of the shaft as a foundation for the head house and filling around the shaft to subgrade can be completed under Contract 20 without further highway changes. Designs were made of stop shutters for unwatering the tunnel under full reservoir head.

Tunnel Vent. — Designs were made for a vent hole between Shafts 11 and 12 about 5,700 feet east of Shaft 12 extending from the roof of the tunnel 150 feet to the surface of the ground to vent air that, except for such a vent, could accumulate in the tunnel east of the intake. If air were allowed to accumulate at this point, it might under certain conditions of future operation be vented suddenly under

high pressure and damage the head house at Shaft 12. This vent consists of a 6-inch copper tube grouted in an 8-inch drill hole. At the surface this tube is designed to be enclosed in a concrete block and capped with a cast-iron vent head.

Caisson Core Wall at Main Dam. — Designs were made for a concrete core wall from the original surface to sound rock in the bottom of the valley at the site of the main dam to be constructed by sinking from the bottom of an open-cut trench a row of caissons, each 9 feet thick and 45 feet long. These caissons are designed to be sealed to the ledge and to each other in the same manner as is being successfully done under Contract 36 at the site of the dike. The design calls for thirty-eight caissons including the experimental caisson sunk under Contract 32, or seven more than at the dike, where thirty-one have been sunk. Studies were made of the economical depth of open-cut trench to be first excavated before starting the sinking of caissons and the bottom of the trench in the deepest portion of the valley was fixed at about 35 feet below the river level, the remaining distance to ledge being about 90 feet. Each caisson was designed with three 4-foot wells the same as at the dike, the two end wells being for handling muck and the central well for handling men.

Pumping Ground Water. — Studies were continued of the permeability of foundation materials at both the main dam and dike sites. Excellent data are available as a result of the continued pumping from the caissons being sunk under Contract 36 and the renewal, on August 15, of pumping from the experimental caisson at the main dam site.

At the dike site pumping was continued throughout the year. On December 1, 1932, pumping was at the rate of 1,237 gallons per minute and the ground water level at the caisson pump sump had been lowered about 60 feet below the original brook level. On January 21, pumping was taken over by the contractor and after completing the installation of additional pumping capacity the rate averaged about 3,200 gallons per minute. On November 30, the ground water level had been lowered about 96 feet. Our studies have indicated that the glacial material in the rock valley is coarser at the lower elevations near the ledge. The average permeability of materials below the ground water surface at the commencement of pumping operations was about 16 million gallons per acre per day under unit slope at 50° F, and at the end of the year about 28.

At the experimental caisson at the dam site, pumping was renewed August 15, following the installation of additional pumps and averaged 2,200 gallons per minute at the end of the year. The ground water level at the caisson pump sump was held practically constant 15 feet below the water level in the river. Preliminary studies indicated that the average permeability of the glacial materials in the main Swift river valley in the vicinity of the main dam is about 35 million gallons per acre per day under unit slope at 50° F and probably the same at all depths below the original surface. Our studies indicated that a large portion of the water pumped was drawn from the old river bed between the upstream and downstream cut-off dams at the entrance and exit of the river diversion conduit completed under Contract 30 and that in spite of the fact that the experimental caisson was not sunk in the deepest part of the rock valley, a considerable additional lowering of the ground water level would result if the old river bed were dried up. Accordingly, designs were made for an extension of the discharge pipe line in the caisson a distance of about 1,000 feet to a point above the upstream cofferdam. This design includes a provision for future weir boxes at the entrance to this steel pipe, the entire layout being designed to fit the requirements of a contractor constructing a complete caisson core wall at the main dam site.

Main Dam Spillway. — Studies were made to determine the best location for the main spillway of Quabbin Reservoir. Borings indicate good locations at either end of the dam. At the east end a channel from the spillway can be excavated in solid ledge to a point much closer to the river than in the case of the westerly site. If the easterly site should be adopted for the main spillway, an additional emergency spillway may easily be provided at the westerly site.

Clearing Reservoir. — Studies were made of methods of clearing the Quabbin Reservoir site and of the extent of shallow flowage at the margins.

Main Dam and Dike. — Studies were continued of designs for the main dam and dike. Explorations were continued under the direction of the headquarters office

by borings and borrow pits to locate suitable material for the construction of embankments. Designs were made for a sluicing bin in which to conduct large scale experiments in the washing of materials available for dam construction. This sluicing bin was constructed in Enfield in the yard of the old Tebo mill and the engineering force supervised the washing tests. The bin was designed with a width of 15 feet between wooden sidewalls about 4 feet high and with a concrete bottom, sloped one to fifty into a depression at one end for the collection of fines during washing with an overflow to a sump from which the circulating water is pumped to the hose nozzles.

Rutland-Holden Sewer. — Designs were made for a new open-nozzle type of measuring weir for use on the small sewage pipe lines of the Rutland-Holden sewer. This weir is referred to as an open nozzle because it bears the same relation to a nozzle that an open-venturi does to a venturi meter. Castings made from these designs were tested and rated at the laboratory of the Massachusetts Institute of Technology. One of these nozzles will be installed to measure the discharge from the Rutland State Sanatorium into the upper end of the 10-inch sewer line, another to measure the discharge from the U. S. Veterans' Hospital into the upper end of a 10-inch branch line and another, at the Holden-Worcester line, to measure the discharge from the 16-inch outlet into the trunk sewerage system of the city of Worcester.

Photographic Records. — The taking of moving pictures from time to time to illustrate the progress of construction was continued.

Highway Relocation. — Studies were continued of highway relocation which will be required because of the construction of Quabbin Reservoir.

Transmission Line Relocation. — Studies were made of the relocation of the 66,000-volt transmission line of the New England Power Company between Leverett and Ware which will be required on account of the construction of Quabbin Reservoir. This transmission line crossed the Swift River and its west branch west of Enfield Center and crossed Beaver Brook just north of the dike site. A 22,000-volt circuit followed the same right of way from the substation at Ware to one at Enfield serving Enfield and Belchertown and a telephone line extended the entire length of the 66,000-volt line. These lines and the substation in Enfield were also required to be relocated. The total length of original line affected was about 35,050 feet and the length of relocation 44,780 feet. Studies were also made for increasing the height of towers and other required alterations on the 110,000-volt line of the New England Power Company between Davis Bridge, Vermont, and Millbury at points where this line crosses the north end of the Quabbin Reservoir site.

Railroad Valuation. — Valuation studies of that portion of the Athol Branch of the Boston and Albany Railroad which will be affected by the construction of the Quabbin Reservoir were continued.

Wachusett-Coldbrook Tunnel Division — Holden Office

The Wachusett-Coldbrook Tunnel Division continued in charge of all work in connection with improvements on the Ware River watershed, of the location and construction of the Rutland-Holden sewer, of the maintenance and operation of the Ware River intake works and the Wachusett outlet works, of a portion of the surveys for highway relocation in the Quabbin Reservoir area, and of field studies of materials and methods of construction of the main dam and dike.

Office Work

Studies were continued of the feasibility of various methods of diverting from the Ware and Wachusett watersheds the sewage from institutions in Holden and Rutland. Topographic and real estate plans were prepared and studies made for the Rutland-Holden sewer. Monthly estimates and working drawings were prepared for Contract 39. Real estate plans were prepared of miscellaneous property in the Ware River watershed, final tracings being made of about 600 acres. Daily rainfall and temperature records were continued at the White Valley meteorological station and daily rainfall records at West Rutland and continuous records of the flow of the Ware River at the intake building were kept. The division continued its cooperation with the Enfield office in the studies and preparation of plans for the relocation of highways which will be made necessary by the construction of Quabbin

Reservoir. For contract use and also for submission to the State Department of Public Works and the County Commissioners of Franklin County, plans were prepared for a section of the extension of the relocated Belchertown-Pelham highway between Cooleyville and New Salem Center. The construction of this new highway west of Quabbin Reservoir is under the supervision of the Enfield office and is hereinafter described. Studies were continued of materials, comparative costs and methods of construction of the proposed main dam and dike.

Field Work

Topographic surveys were continued in connection with the studies of various methods of the disposal of sewage and other wastes from institutions in Holden and Rutland. The topographic surveys made in connection with these studies and the preparation of sewer contract plans covered about 250 acres. Rod soundings and test pits were continued to investigate the material along the line of the proposed Rutland-Holden sewer and in the vicinity of the proposed highway relocation west of Quabbin Reservoir. Lines and grades were given for construction on Contract 39. Photographs of the construction work were made by the Enfield office. Topographic surveys covering about 60 acres were made in connection with the location of new highways in the Quabbin Reservoir area and the preparation of highway contract plans. Real estate surveys were made covering about 284 acres of various properties in the Ware River watershed and about 6 acres along the line of the Wachusett-Coldbrook Tunnel. Additional stone bounds were set during the year. A triangulation system was established in the Ware River drainage area and tied to that previously established by the Hardwick office.

The State Department of Public Health continued its cooperation with this division in the analysis of samples of water and sewage effluents. The two chlorinator stations on the Ware River watershed, one to chlorinate the sewage effluent from the treatment plant of the temporary Rutland Prison Camp and Hospital, and the other on Mill Brook below the Rutland State Sanatorium and the Central New England Sanatorium, were kept in condition for use but due to the fact that no water was required to be diverted at the Ware River intake works they were not operated.

Operation of Ware River Intake Works

Maintenance of the Ware River intake works was continued. No water was diverted into the tunnel during the year. The tunnel was entered for inspection through Shaft 8 on January 17 and the doors of the steel bulkhead, 2,200 feet west of the shaft, were fastened open to prevent any possibility of damage to the hinges or fastenings when holing through between Shafts 8 and 9 at the heading about 2,800 feet further west. The main butterfly valves at the top of Shaft 8 were closed and the valve pit filled with water when the tunnel was holed through January 24. The blast was heard in the intake building but was not perceptible at the head house over Shaft 4. The next day the tunnel was again entered, the shaft, tunnel and bulkhead were found in good condition and the bulkhead doors were fastened in a closed position.

Miscellaneous Construction

Minor alterations were made at the Wachusett outlet works consisting of the relocation of the temporary transformer platform. Additional shrubbery and trees from the Metropolitan District Commission nurseries in Stoneham and from private nurseries were transported to Shafts 1, 4 and 8 and transplanted.

A small labor force was employed throughout the year on miscellaneous work in caring for the grounds at the Ware River intake, Wachusett outlet and Shaft 4 head house, setting stone bounds, filling cellar holes, grading and cleaning up at the sites of buildings removed from the Ware River watershed and other miscellaneous work. The average number of men employed in this work was two and the maximum six.

Progress of Contracts

Contract 39. — Bids were opened July 7 for constructing a trunk sewer in the towns of Rutland and Holden to a point of connection with the Worcester sewerage system. Ten bids were received for constructing the entire sewer ranging from $184,327.50 to $375,818.50, fifteen for constructing the east portion only, ranging

from $109,341.50 to $282,595.00, and seventeen for constructing the west portion only, ranging from $86,546.50 to $219,975.80. The contract for the entire sewer was executed July 11 with James J. Coughlan & Sons, Inc., Boston, the low bidder. The contractor established his field office in the village of Jefferson July 19 and commenced the clearing of the right of way July 25. Trench excavation was done by two 1-cubic yard back diggers. In addition a ½-cubic yard clamshell bucket crane was used where ledge was encountered. The trench was excavated entirely by the open trench method, no sheeting or bracing being used. The machine diggers also handled the pipe into the trench, excavating the trench to grade only one 16-foot pipe length in advance of the laying of the pipe. Two bulldozers were used to assist in backfilling and one in pipe delivery.

The material for constructing embankments was obtained by the contractor from pits on private property as well as from lands of the Commonwealth. All foundation embankments were generally spread in 6-inch layers using two bulldozers and rolled by a 10-ton roller, this equipment being transferred to different points of the work as needed. Two 1-yard steam shovels were used in the borrow pits.

The first trench digging and pipe laying plant started laying pipe August 28 and the second September 20. A total length of 12,928 feet was laid, 7,692 feet by the first plant and 5,236 feet by the second. The average rate of pipe laying since August 1 was about 735 feet per week, the maximum in any one week being 2,239 feet.

At the Worcester Brook embankment, excavation of unsuitable foundation material was started August 14, at Asnebumskit Brook August 26, and at Eagle Lake September 6. At the end of the year these three embankments were practically completed except for soil dressing to an elevation well above the grade of the pipe so that a shallow trench will need to be excavated for the pipe. At the Newell Road embankment, excavation of unsuitable foundation material was started September 21. At the end of the year the embankment was about 40% completed.

Six reinforced concrete culverts were constructed between August 31 and November 16. A ½-yard clamshell crane was used in excavating for the culverts and a 1-bag mixer was used for the concrete.

Nineteen of the required 129 manholes were constructed. Steel forms were used. The value of work included in contract estimates to November 29, the date of the latest estimate, was $56,015.75, of which 90% was approved for payment. The contractor's force averaged forty-five men, the maximum being seventy-six for the week ending October 7.

The total work done and materials furnished to date under the principal items of Contract 39 are as follows:

Excavating and refilling trench	11,430 lin. ft.
Earth excavation, except in trench	10,510 cu. yds.
Rock excavation	1,984 " "
Furnishing and laying 10-inch pipe	4,946 lin. ft.
Furnishing and laying 12-inch pipe	2,797 " "
Furnishing and laying 16-inch pipe	5,067 " "
Foundation embankment	21,425 cu. yds.
Concrete in manholes	88 " "
Concrete, except in manholes	421 " "

Contract 42. — Contract 42, an agreement with the City of Worcester, for the use of the Worcester sewerage and treatment works, for the disposal of sewage from Rutland and Holden, was executed May 1. Under this agreement the city constructed 2.11 miles of vitrified tile pipe sewer, mostly 15 and 18-inch, from the Holden-Worcester line to connect with the Worcester trunk system of sewers at a point on Salisbury Street about 1,600 feet north of Flagg Street. An inspection of the completed sewer was made by the division November 14. In accordance with the provisions of the agreement, the Commission paid the city a total of $325,000 as compensation for the construction of the sewer within the city limits and for the right to enter the city's sewerage system and treatment works.

Coldbrook-Swift Tunnel Division — Hardwick Office

The Coldbrook-Swift Tunnel Division continued in charge of the construction of the Coldbrook-Swift Tunnel section of Quabbin Aqueduct and of river surveys along the Ware, Swift and Chicopee rivers.

Office Work

Tunnel cross sections were plotted and excavation and masonry volumes computed therefrom. Semi-monthly estimates were prepared for Contract 20. Topographic maps were made of areas on Danforth Brook, Prince River and at the tunnel spoil bank at Shaft 9. The preparation of geologic field notes and specimens for a permanent geologic record was continued.

Field Work

Lines and grades were given for construction on Contract 20. About 430 acres of topography were taken along the Ware River and tributaries below the intake and about 25 acres in the vicinity of Shafts 9 and 12. About 35 acres at and in the vicinity of industrial plants on the Ware River were surveyed and cross sections taken of the river at various points near these plants. The State Department of Public Health continued its cooperation in the analysis of samples of drinking water used in the different contractors' camps. Test pits were dug to investigate the possibility of a gravity water supply for the future head house and service building at Shaft 12. Taking of samples of concrete for testing was continued and an analysis was made of rock crushed by the contractor at the various shafts to determine its fitness for tunnel concrete aggregates. Records were continued of the amount of cement used and required to be used at all points of the work. Photographs of the construction work and of rock formations of geological interest were continued. Geological investigations were continued in connection with the tunnel construction. The division also continued its cooperation with the Enfield office in geological investigations in connection with the diversion tunnel completed under Contract 30, the dike caisson core wall under Contract 36, surveys for the spillway and spillway channel at the main dam and for the new highway west of the proposed reservoir. Special castings for Contract 20 were inspected at the foundry.

A small labor force was employed from time to time constructing guard rail for the relocated highway near Shaft 12 and other miscellaneous work.

Collection of Stream Flow and Water Power Data

The collection of data pertinent to the determination of the water power available and developed at various plants on the Ware, Swift and Chicopee rivers and to the determination of flows at various points under varying conditions, was continued. Recording stream gaging stations were continued at White Valley, Ware and Bircham Bend.

This office continued the investigations of the quality of the water in the Ware River made in cooperation with the laboratory at Enfield, the collection of the necessary hydraulic data in connection with this work being carried on by this office.

Progress of Contracts

Contract 20. — Contract 20, for the construction of the Coldbrook-Swift Tunnel section of Quabbin Aqueduct, through the towns of Barre, Hardwick and Greenwich, continued in force throughout the year. This tunnel extends 10.4 miles from the end of the completed Wachusett-Coldbrook section to the Swift River intake in the town of Greenwich.

At the end of the year about 81% of the value of the work was completed. This included the completion of the tunnel excavation, a length of about 16,332 feet of tunnel being excavated during the year, making a total under this contract of 54,831 feet. It also included the lining with concrete of about 25,000 feet of tunnel. A length of about 29,862 feet of tunnel remains to be lined under this contract. The selection, crushing and screening of tunnel spoil for use as concrete aggregates were continued at all shafts. Concrete mixing plants were set up and operated at the top of Shafts 9 and 11 and the concrete was placed in sidewalls, arch and invert from four tunnel plants, one in each heading from each of these two shafts. A mixing plant was also being set up at the lower intake just outside the tunnel portal. Excellent progress continued to be made in the excavation of this hard rock tunnel. The average weekly excavation for the year in eight headings was 98.9 feet per heading. The maximum in one heading was 138 feet in the week ending April 8 in the east heading from Shaft 10. Only 1,202 feet of permanent timbering was required to be placed during the year, making a total of 1,590 feet of tunnel or 2.90%

of the length excavated under this contract, requiring permanent timbering. This makes a remarkably low total of 1,971 feet or 1.52% of the entire length, 24.6 miles, of Quabbin Aqueduct. The average weekly progress in placing concrete lining from four tunnel plants was 298 feet per plant. The contractor continued to employ local physicians who made weekly reports on the health of his employees and on the sanitary conditions at each of his camps and to employ a safety engineer for the improvement of working conditions in the tunnel. The excavation of the entire 10.4 miles of tunnel under this contract was completed with no fatal accidents.

The following is a summary of the difference in line and grade at the points where the excavations met between shafts.

Shaft	Distance Apart	Difference Line	Difference Grade	Point of Meeting
8– 9	12,412 ft.	.06 ft.	.06 ft.	4,998 ft. from Shaft 8
9–10	14,501 ft.	.63 ft.	.11 ft.	7,611 ft. from Shaft 9
10–11	15,840 ft.	.12 ft.	.02 ft.	8,278 ft. from Shaft 10
11–12	16,757 ft.	.10 ft.	.05 ft.	8,254 ft. from Shaft 11
12–Portal	319 ft.	.00 ft.	.02 ft.	230 ft. from Shaft 12

The value of work included in contract estimates during the year was $1,552,245.20, or a total to November 24, the date of the latest estimate, of $4,041,658.33, of which 90% was approved for payment.

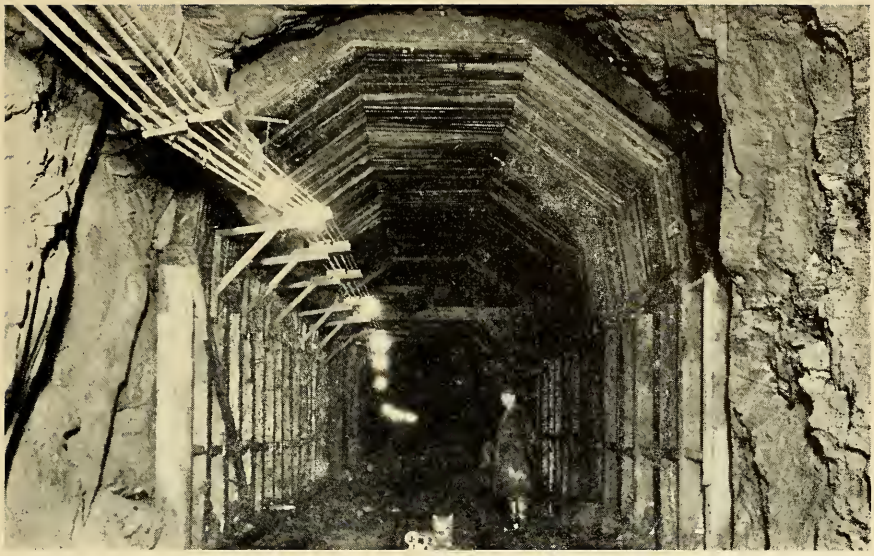
Shaft 9. — Tunnel excavation was completed January 24, the lengths excavated being as follows:

Location	To Nov. 30, 1932	Year ending Nov. 30, 1933	Total
East heading	6,587 ft.	827 ft.	7,414 ft.
West heading	6,678 ft.	933 ft.	7,611 ft.
Total	13,265 ft.	1,760 ft.	15,025 ft.

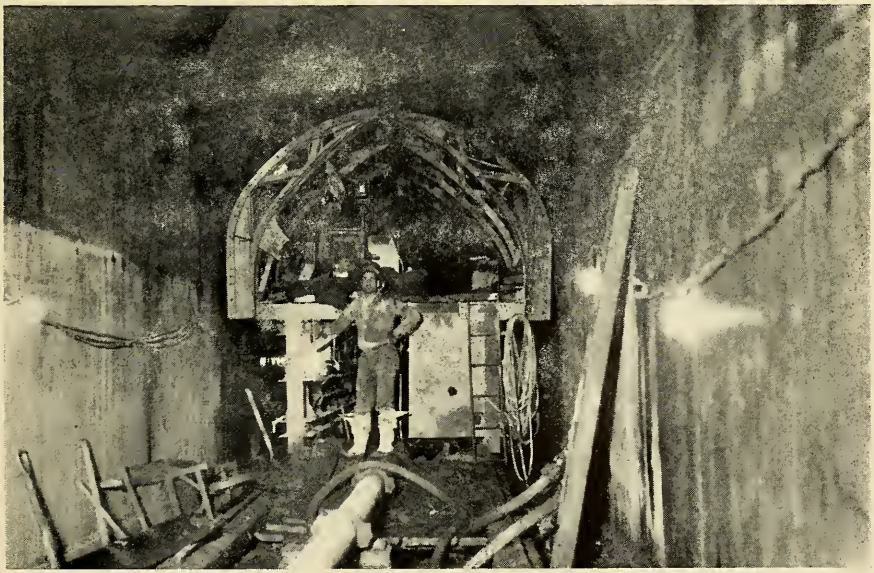
Tunnel driving was continued by the full-face method. The quality of the rock encountered varied considerably, a good deal of it being too soft to be used as concrete aggregates. In the east heading an additional 47 feet required permanent timbering; none being required in the west heading. An additional 117 feet of the tunnel roof in the west heading was treated with gunite to prevent weathering in the seams and scaling off. On January 24 the east heading was holed through to the west end of the previously completed Wachusett-Coldbrook section of Quabbin Aqueduct. Excavation in the west heading was then stopped and the doors in the steel bulkhead about 2,200 feet west of Shaft 8 were fastened in closed position to prevent any drainage from the contractor's operations in the tunnel from entering the Wachusett Reservoir by way of the completed section of the tunnel. The average weekly progress of tunnel excavation for the year was 110 feet easterly and 122 feet westerly, the maximum progress being in the week ending January 21, when 127 feet were excavated in the east section and 124 feet in the west section.

Final trimming and grading of the tunnel were commenced promptly upon the completion of excavation. The crushing, screening, washing and mixing plant was completed at the top of the shaft in April. To supplement the quantity of available material obtained from the tunnel excavation crushed stone and screenings were hauled from Shaft 10 and gravel and sand were obtained from a borrow pit adjacent to Shaft 9. Two tunnel lining plants were erected, one in the east heading at the junction with the previously lined Wachusett-Coldbrook section and one in the west heading 6,208 feet from the centerline of the shaft. On May 6 the first concrete was poured in the east heading and on June 6 in the west heading. Thereafter, except as interrupted for a brief time by labor difficulties, concreting was continued with good progress in both headings until November 13, at which time the lining from this shaft was completed with the exception of a length of 41 feet at the bottom of the shaft and an additional length of 463 feet of invert. The average weekly progress of the tunnel lining was 322 feet in the east heading and 326 feet in the west heading, the maximum being in the week ending June 24, 497 feet in the east heading and 499 feet in the west heading. The contractor's force averaged sixty-two men, the maximum being 124 during the week ending September 23. The average number of persons occupying the camp was fifteen, the maximum population being forty-one during the week ending August 26.

There was no material change in plant items required for the tunnel excavation. The surface plant for crushing and screening was similar in many respects to that



Contract 20. — Coldbrook-Swift Section of Quabbin Aqueduct, Permanent Timbering in the West Heading at Shaft 9.



Contract 20. — Coldbrook-Swift Section of Quabbin Aqueduct, Arch Forms for Tunnel Lining at Shaft 11.

used by the contractors on the Wachusett-Coldbrook section. The same dragline scraper operated over the spoil bank to bring the material to a grizzly, from which a short conveyor-belt carried the material to a screening and washing plant, using the same rotary screen. Fine particles in suspension were carried to settling basins beyond the muck piles where the water was clarified. Material of suitable size for aggregate was carried by conveyor-belts to the stone and sand storage piles. The screens fed the coarse material into a crusher from which it was returned to the screen. A heavy timbered trap tunnel under the two aggregate storage piles was used, the same as on the Wachusett-Coldbrook section. However, instead of batching the aggregates and dropping them dry down the shaft, all concrete was mixed at the surface in two 1-cubic yard mixers, the cement, sand and stone being proportioned by weight for each batch and the water by tank measurement. Bulk cement was shipped in containers holding about twenty-five barrels each, twelve in a car. These containers were emptied through bottom doors into the contractor's bin near the railroad siding, holding about six hundred barrels. Specially-constructed trucks carried the cement to the shaft where it was stored and weighed as required for the mixer. Each batch was emptied into a small hopper from which it dropped down the shaft through an 8-inch pipe to a hopper at the bottom, from which the cars were filled by a hand-operated shutter. The concrete cars were of steel specially designed with the bottom slanting about 45° to one side which was hinged at the top. This swinging side closed against a rubber gasket, giving a water-tight joint. A train consisted of four cars, each holding two batches. The tunnel plant used for placing concrete lining differed in many respects from that used on the Wachusett-Coldbrook section. The contractor purchased the tunnel forms used on the latter section and rebuilt them by cutting them into two sections, the sidewall forms to about 2 ft. 2 in. below the springing line of the finished arch, being set up in advance of the arch forms. All forms in use were carried ahead on a jumbo in one operation instead of being collapsed in sections and telescoped from end to end of the work as was the case in the Wachusett-Coldbrook section. Also the placing of the invert, instead of being an entirely separate operation, followed immediately after the placing of sidewalls and arch. As rebuilt, the forms consisted of 125 feet of sidewall forms followed by 125 feet of arch forms and preceded by an incline about 60 feet long, the whole supported on wheels on a 6 ft. 6 in. gage track, accurately placed to line and grade. This track was of rails spiked to 6 in. x 10 in. longitudinal stringers, which were picked up in sections from behind the forms, passed forward and relaid in front. A working platform at about mid height of the tunnel was reached by the incline ahead of the sidewall forms. A concrete gun used for placing the arch and invert concrete was hung under the platform and fed through a steel hopper of about 1 cubic yard capacity set in the platform. The sidewall forms were filled by dumping directly from the concrete cars. The arch forms were raised and lowered by oil-operated jacks. The sidewall forms moved in and out by turnbuckles. The arch concrete was placed through a 6-inch line from the concrete gun carried along the working platform and extended up through first one and then another of a series of trap doors in the arch forms. The invert was also cast by the use of a gun and pipe removed in sections as the work progressed. The invert was screeded by steel templets, guided by a 3-inch ledge previously cast with the sidewall at the elevation of the intersection with the invert. Except as above described, no important items of plant were added during the year. The largest pump in use had a rated capacity of 2,000 gals. per min. under 300-ft. head driven by a 200-horsepower motor. The combined compressor capacity was reduced after the completion of excavation to 1,100 cu. ft. per min.

Shaft 10. — Tunnel excavation was completed on October 16, the lengths excavated being as follows:

Location	To Nov. 30, 1932	Year ending Nov. 30, 1933	Total
East heading	3,810 ft.	3,080 ft.	6,890 ft.
West heading	3,797 ft.	4,481 ft.	8,278 ft.
Total	7,607 ft.	7,561 ft.	15,168 ft.

Tunnel driving was continued by the full face method. In the east heading an additional 903 feet required permanent timbering, 22 feet required temporary timbering and 1,010 feet of the tunnel roof was treated with gunite to prevent

weathering in the seams and scaling off. In the west heading 609 feet of the tunnel roof was treated with gunite. On August 10 the east heading was drilled through into the west heading from Shaft 9, leaving a 7-foot plug of rock to cut off water drainage and air circulation. This plug was holed through October 15 and on October 16 the west heading was holed through into the east heading from Shaft 11. The average weekly progress of tunnel excavation for the year was 86 feet easterly and 101 feet westerly, the maximum progress being in the week ending April 22, when 137 feet were excavated in the east section and 104 feet in the west section.

After holing through, all work at this shaft was discontinued except pumping which was continued until November 21. The contractor's force averaged sixty-five men, the maximum being ninety during the week ending January 7. The average number of persons occupying the camp was sixteen, the maximum population being twenty-nine during the weeks ending December 17 and January 21.

There was no material change in plant items during the year. The largest pump in use had a rated capacity of 1,100 gals. per min. under 450-ft. head driven by a 200-horsepower motor.

Shaft 11. — Tunnel excavation was completed April 20, the lengths excavated being as follows:

Location	To Nov. 30, 1932	Year ending Nov. 30, 1932	Total
East heading	5,843 ft.	1,719 ft.	7,562 ft.
West heading	6,193 ft.	2,061 ft.	8,254 ft.
Total	12,036 ft.	3,780 ft.	15,816 ft.

Tunnel driving was continued by the full face method. In the east heading 252 feet required permanent timbering. The average weekly progress of tunnel excavation for the year was 86 feet easterly and 103 feet westerly, the maximum progress being in the weeks ending December 10 and February 25, when a total of 221 feet was excavated in both headings. The final trimming and grading of the tunnel was commenced promptly upon the completion of excavation and two tunnel lining plants were erected, one in the east heading 7,300 feet from the centerline of Shaft 11 and one in the west heading 7,952 feet from the shaft. The crushing, screening and washing plant was set up early in the year and used for experimentation on the quality of the aggregates until concreting was started at the shaft. On July 3 the first concrete was poured in the west heading and on August 22 in the east heading. On September 19, after the tunnel excavation had been holed through from Shaft 12, a bulkhead was constructed between Shafts 11 and 12 to cut off the circulation of cold air. At the end of the year the lining had been carried to within 2,621 feet of the shaft easterly and 1,249 feet westerly. The average weekly progress of the tunnel lining was 331 feet in the east heading and 389 feet in the west heading, the maximum being in the weeks ending October 28 and November 11, 525 feet in the east heading and 524 feet in the west heading. The contractor's force averaged seventy-nine men, the maximum being 140 during the week ending October 14. The average number of persons occupying the camp was twenty-three, the maximum population being forty-seven during the week ending September 16.

Except for the tunnel lining equipment, there was no material change in plant items during the year. The screening, washing and mixing plant and the tunnel lining plant were similar to that used at Shaft 9 and previously described. The largest pump in use had a rated capacity of 1,000 gals. per min. under 350-ft. head driven by a 150-horsepower motor.

Shaft 12 and Swift River Intake. — Tunnel excavation was completed June 23, the lengths excavated being as follows:

Location	To Nov. 30, 1932	Year ending Nov. 30, 1933	Total
East heading	5,330 ft.	3,173 ft.	8,503 ft.
West heading	172 ft.	58 ft.	230 ft.
Portal	89 ft.	0 ft.	89 ft.
Total	5,591 ft.	3,231 ft.	8,822 ft.

Tunnel driving was continued in the east heading by the full face method.

On June 14 the east heading was holed through to the west heading from Shaft 11. The remaining 58 feet in the west heading was then excavated by the heading and

bench method, holing through to the portal June 23. The average weekly progress of tunnel excavation for the year was 113 feet (in the east heading), the maximum progress being 134 feet during the week ending December 17, 1932.

Spoil from the tunnel excavation continued to be used to cover swampy areas in the vicinity of the lower intake and as additional riprap along the sides of the lower intake channel. Tunnel spoil was also used for building the temporary relocation of the highway just east of the shaft at an elevation above the future flow line of Quabbin Reservoir. Guard posts were set along the new highway location. Castings for stop log grooves to be installed in the shaft were delivered at the site, commencing the middle of June.

After holing through, all work in the tunnel at this shaft was discontinued except pumping. Beginning August 5, the contractor resumed with a small force, the erection of the crushing, screening, washing and mixing plant, using equipment transferred from Shaft 9. This plant is being located at a point above the cut and cover section of the lower intake just west of the tunnel portal in preparation for tunnel lining operations. The contractor's force averaged thirty-three men for the year and fifty until June 14, the maximum being fifty-three in the four weeks ending January 14, April 8, May 13 and 20. The average number of persons occupying the camp was nine, the maximum population being twenty-one during the week ending February 11.

There was no material change in plant items for the tunnel excavation. At the end of the year the contractor was engaged in installing additional equipment for tunnel lining including that transferred from Shaft 9. The largest pump in use had a rated capcaity of 650 gals. per min. under 150-ft. head driven by a 75-horsepower motor. The combined compressor capacity was reduced to 750 cu. ft. per min.

The total work done and materials furnished to date under the principal items of Contract 20 are as follows:

	Shaft 9	Shaft 10	Shaft 11	Shaft 12 and Intake
Earth excavation for shafts (cu. yds.)	84	318	225	*
Rock excavation in shafts and in tunnel within 50 ft. of shafts (cu. yds.)	2,310	3,617	2,660	1,445
Excavation in tunnel, except within 50 ft. of shafts (cu. yds.)	101,254	99,970	105,264	58,019
Shaft and tunnel drainage (lin. ft.)	11,281	4,090	9,214	2,241
Earth excavation in open cut (cu. yds.)	—	2,500	1,803	35,729
Rock excavation in open cut (cu. yds.)	—	435	106	2,181
Forms for concrete lining in shafts (lin. ft.)	178	397	258	—
Forms for concrete lining in tunnel (lin. ft.)	13,612	—	10,633	—
Concrete masonry in shafts (cu. yds.)	400	929	611	—
Concrete masonry in tunnel (cu. yds.)	28,343	—	22,461	—
Concrete masonry not in shafts or tunnel (cu. yds.)	—	—	1	1,062
Permanent timbering in tunnel (M ft. B. M.)	34	215	54	25
Temporary timbering in tunnel (M ft. B. M.)	7	—	4.5	—
Portland cement (bbls.)	45,935	1,909	35,874	2,212
Gunite protective coating of tunnel rock (lin. ft.)	3,648	3,453	—	—
Refilling and embanking (cu. yds.)	—	1,625	—	2,753
Miscellaneous cast iron, wrought iron and steel (lbs.)	23,400	3,415	—	9,251
Riprap (cu. yds.)	—	—	—	822
Paving (cu. yds.)	—	—	—	21

*Included in item, "Earth excavation in open cut."

Electric power for all contract requirements was purchased by the contractor. The total consumed at the different shafts during the year was as follows:

	K.W.H.
Shaft 9	1,330,200
Shaft 10	3,084,869
Shaft 11	3,104,400
Shaft 12	1,141,400
Total	8,660,869

The total electrical power consumed on Contract 20 from April 23, 1931, to November 30, 1933, was approximately 19,048,000 kilowatt hours, the total length of tunnel excavated being 54,831 linear feet and the total length of tunnel lined being about 25,000 linear feet.

Quabbin Reservoir Division — Enfield Office

The Quabbin Reservoir Division continued in charge of the field work in the Swift River valley in connection with the proposed Quabbin Reservoir including topographic and real estate surveys, cemetery removal work, and the soil testing

and water analysis laboratories. The division also continued in charge of construction work at the main dam and dike sites and was in charge of the construction of the Belchertown-Pelham highway and its extensions and of the relocation of the high tension transmission line of the New England Power Company.

Miscellaneous Office Work

Semi-monthly estimates for Contracts 36 and 41, monthly estimates for Contracts 23, 30, 40 and 43, and a final estimate for Contract 30 were prepared. For contract use and also for submission to the State Department of Public Works and the County Commissioners of Hampshire and Franklin Counties, plans were prepared of the relocated Belchertown-Pelham highway and its extensions to and north of New Salem, except for a section between Cooleyville and New Salem Center which was in charge of the Holden office. The new location follows closely the existing highway from Belchertown through Pelham Center to a point about 1 mile north of the Pelham-Shutesbury line. The new route then runs northeasterly and crosses the west branch of the Swift River about 0.7-mile downstream from its crossing of the Cooleyville-Shutesbury highway. It then passes close to the southerly side of the village of Cooleyville and continues northeasterly over the top of New Salem hill about 0.1-mile northerly of New Salem Center and crosses the Millington-North New Salem highway about 0.8-mile southerly of North New Salem village. Thence it extends easterly across the middle branch of the Swift River and northeasterly again along the Millington-Orange highway to a point just north of the New Salem-Orange town line at the junction with a highway to Athol. The new highway will have a 24-foot bituminous macadam surface with 3-foot gravel shoulders.

Real estate plans were prepared along the entire line of the relocated Belchertown-Pelham highway and extensions. Revised topographic plans of the main dam site were made. Photographs of the progress of construction carried on under the supervision of this and other divisions were taken by this division. Meteorological records at Enfield were continued.

Miscellaneous Field Work

Lines and grades were given for construction on Contracts 23, 30, 36, 40, 41, 43 and 44. A detailed topographic survey was made for use in a contract for a caisson core wall at the main dam site. Pumping from the exploratory caisson at the dike site was continued until January 21, when the lowering of the ground water level at the dike site was taken over by the contractor for the construction of the caisson core wall. Holes were drilled through the concrete walls of the experimental caisson at the main dam site and piping installed to increase the intake capacity. Additional electric wiring and pumping equipment were installed in the caisson. The pipe line for the discharge from the pumps was extended underneath the railroad track to a weir box constructed on the bank of the old river bed from which the river had been diverted by low cofferdams constructed under Contract 30. The pumps in the caisson were again operated for the lowering of the ground water level, commencing August 14. Commencing November 1, work was begun on the construction of a further extension of the discharge line from the pumps to a point above the upstream cofferdam. Daily readings of ground water level in numerous test wells were taken during the pumping operations at the dike and the dam. Additional topographic and real estate surveys and cross sections were made for the location of the new highway west of Quabbin Reservoir and additional test pits were dug to determine material suitable for their construction. Sub-surface investigations were made by test pits at and near sites proposed for the main dam spillway and spillway channel on both the east and west sides of the valley. In the late summer, repairs were made on the dam across the Swift River at Enfield. New roof trusses, roof and other repairs were made on the garage in Enfield formerly known as Coolbeth's Garage which was gutted by fire March 6. This garage is used for garaging trucks and other equipment attached to this division and equipment of the Department of Public Works.

In connection with new highway construction, a narrow section along the easterly side of the Pelham Center Cemetery was relocated in an area of 0.4-acre

acquired for the purpose along the west side of the cemetery. But few of the stones contained legible inscriptions and some of the bodies had been buried 125 years. The work of relocation was done by this division with labor engaged directly for this work. Careful surveys were made in advance and in the new location headstones and remains were placed in the same relative positions.

Reservoir — General

Topography. — Practically no progress was made during the year on the general topographic maps within and adjacent to the proposed reservoir. To date 25,970 acres or 40.6 square miles have been surveyed. About 13,000 feet of the drainage divide was surveyed, making a total to date of 37,200 feet.

Real Estate. — Additional property described in applications by owners for sale of real estate was located and sketches made showing the approximate location. Comprehensive real estate surveys and analyses and descriptions of deeds were continued. Real estate surveys during the year cover 466 acres, making a total to date of 59,355 acres or 92.74 square miles. Of this total, 58,203 acres have been plotted at a scale of 1 inch = 200 feet. No additional final tracings were made. Preliminary taking plans were made covering about 79,000 feet of highway location surveyed in Pelham, Shutesbury, New Salem and Orange.

Photography. — The photographing of buildings and cemetery lots within the area to be affected by the proposed reservoir and the making of record prints were continued. During the year 149 photographs of buildings, 51 of cemetery lots and 211 of the progress of construction carried on under the supervision of this and other divisions were taken. Also 284 photographs of property in the Ware River watershed were taken.

Cemetery Removals. — Interments in Quabbin Park Cemetery and the general removal of bodies from existing cemeteries in the reservoir area were continued. The removal of bodies, headstones and monuments has been done by this division with labor engaged directly for this work. During the year work has progressed as shown in the following table:

CEMETERY REMOVALS

		To Nov. 30, 1932	Year ending Nov. 30, 1933	Total
Burial lots in Quabbin Park Cemetery assigned in exchange		208	199	407
Burial lots in Quabbin Park Cemetery sold		1	9	10
Number of releases executed of rights in old lots in Quabbin Reservoir area	to Q. P. Cemetery	28	98	126
	to other cemeteries	111	19	130
Bodies removed from Quabbin Reservoir area	to Q. P. Cemetery	62	589	651
	to other cemeteries	698	70	768
Burials, not reinterments, in Q. P. Cemetery		9	21	30
Headstones moved	to Q. P. Cemetery	42	375	417
	to other cemeteries	317	38	355
Monuments moved	to Q. P. Cemetery	7	61	68
	to other cemeteries	117	12	129

The vault was maintained in readiness for use during the winter months. Work of developing Quabbin Park Cemetery was continued by the planting of shrubbery and the marking, grading and seeding of lots. New planting included 1,200 arbor vitae in the area between the cemetery and Monson Turnpike and in random areas. The average force employed on cemetery development during the working operations was twelve men, the maximum being sixteen on April 26.

Fire Protection. — The fire fighting equipment was continued in readiness for service at all times. Five assistants in the division office were reappointed as deputy forest wardens in each of the towns affected by the reservoir. The equipment and personnel responded during the year to calls for assistance at fourteen forest fires which burned over a toal area of fifty-nine and one-half acres. The apparatus also responded to fires in fourteen buildings.

Laboratories

Soil Testing Laboratory. — The work of exploring, collecting and testing materials to determine their suitability for use in the construction of the proposed main dam and dike was continued and included analyses of the results of the tests conducted in a sluicing bin constructed in the yard of the old Tebo mill in Enfield on the south bank of the Swift River. These sluicing tests were begun September 1, using material from a proposed borrow area northwesterly of the dike site. Tests were continued, using material also from a proposed borrow area northeasterly of the dam site. New equipment was added to the laboratory as testing methods were expanded to include new studies and to keep pace with current developments in soil engineering. Investigations were continued of the glacial deposits on the west side of Beaver Brook valley north of the dike site and on both sides of the Swift River north of the main dam site. Tests were made of top soils stripped from the site of the dike foundation under Contract 36 to determine their suitability for impervious refill of the core wall trench. Tests were also made of top soils to be removed from the site of the main dam foundation and of samples of top soil from other areas below the reservoir flow line to determine their suitability for impervious refill in the construction of the main dam. Sand and gravel for concrete aggregates were tested from the test pits and aggregate plant used on Contract 36.

Chemical and Bacteriological Laboratory. — The collecting and analyzing of water samples were continued in cooperation with the headquarters office and with assistants from the Coldbrook-Swift Tunnel Division. Samples of the water supplies of contractors engaged on work in this and other divisions and of miscellaneous supplies on property controlled by the Commission were collected and analyzed periodically.

Progress of Contracts

Contract 23. — Contract 23, for making borings in the towns of Belchertown, Enfield, Ware, Greenwich and Hardwick, continued in force throughout the year. The work was confined to the exploration of overburden in the vicinity of the main dam, the sinking of wells for the observation of ground water levels and the location of ledge at the proposed spillway sites.

The value of work included in contract estimates during the year was $12,019.91 or a total to November 10, the date of the latest estimate, of $42,793.16, of which 90% was approved for payment. The contractor had one drilling rig in operation during the year and employed an average of two men.

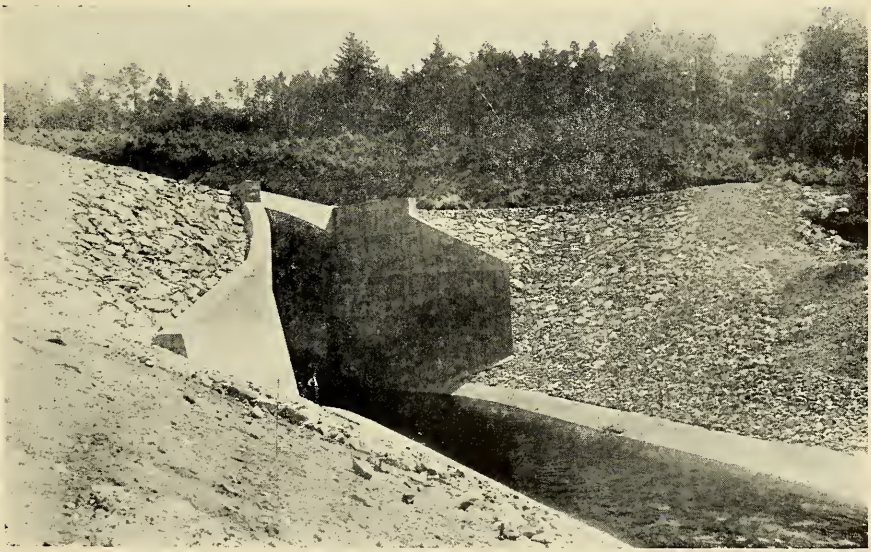
Contract 30. — Contract 30, for constructing the stream control works at the main dam of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware, was continued to completion. Grouting the sidewalls and roof of the tunnel and shaft was started January 22 and completed February 23. On February 8 all work in the tunnel was completed, the tunnel cleaned and pumping equipment removed. Work was discontinued from February 23 to April 24. Riprap and paving around the upstream portal was completed May 20. The approach and outlet channel was excavated through to the river June 2 and the placing of riprap at the inlet to the approach channel was completed June 8. Complete diversion from the old river bed was effected June 7 by the construction of small earth cofferdams at the ends of the approach and outlet channels and all work under the contract was completed July 1.

The value of work included in contract estimates during the year was $73,125.45, the final estimate dated August 29, being $544,610.60. The contractor's force averaged nineteen men, the maximum being sixty-three on December 2, 1932. The contractor's camp was discontinued February 1. No important items of plant were added during the year.

The total work done and materials furnished under the principal items of Contract 30 are as follows:

Excavation in shaft and tunnel	38,347 cu yds.
Earth excavation in open cut	289,160 " "
Rock excavation in open cut	23,522 " "
Refilling and embanking compacted in 6-inch layers	139,252 " "
Other refilling and embanking	132,547 " "
Concrete masonry in tunnel and open-cut conduit	21,183 " "
Portland cement	32,131 bbls.
Cast-iron pipe and miscellaneous iron and steel	92,574 lbs.
Riprap	917 cu. yds.
Paving	793 " "
48-inch Conduit	951 lin. ft.

Contract 30. — Main Dam River Diversion Tunnel, Looking Upstream between Piers at the Foot of Shaft.



Contract 30. — Main Dam River Diversion Tunnel, Upstream Portal and Concrete Lined Approach Channel.

Contract 35. — Contract 35, with the New England Power Company, for the purchase of electricity for experimental work at the dam site, was continued in force throughout the year. Electric power was purchased for use in experimental pumping. The total power furnished was 151,000 kilowatt-hours, costing $3,020, during the year.

Contract 36. — Bids were opened December 9, 1932, for constructing a core wall to sound rock at the site of the dike of Quabbin Reservoir in the towns of Enfield and Ware. Twenty-five bids were received ranging from $995,265.00 to $2,344,177.00. The contract was executed December 28, 1932, with the West Construction Company, the low bidder, who was the contractor on the completed Wachusett-Coldbrook tunnel section of Quabbin Aqueduct. As previously explained, the work consists mainly of excavating an open trench across the valley 40 feet below the level of Beaver Brook, sinking a row of thirty-one concrete caissons from the bottom of this trench to sound rock, and refilling both caissons and trench with impervious materials. On January 16 work on the access road from the main highway was started with one gasoline shovel. On January 17, two gasoline shovels started stripping the site of the open trench and cofferdams. The excavation of the main cut was kept well in advance of the placing of the caisson shoes which were generally set at the grade of the bottom of the open-cut trench specified for payment. Suitable impervious material from the stripping was stored for later use in refilling the open trench. Suitable pervious materials were placed in the cofferdams and spread by a bulldozer in 6-inch layers, wetted and rolled with a 14-ton gasoline roller with bands on the rear rollers. Material too coarse to be placed in this manner was carefully puddled and rolled. Material too fine for use in the cofferdams or elsewhere in the completed structure was wasted in spoil areas downstream from the site. A considerable quantity of fine material was so wasted but sufficient material suitable for the construction of the toes of the future embankment was excavated so that by the end of the year the downstream cofferdam was completed to elevation 430 and the upstream to 438. The original brook level was about elevation 416. The pumps in the exploratory caisson, numbered 13, which had been operated by the Commission since the completion of Contract 32, were taken over by the contractor January 21 and their capacity increased to 3,200 gallons per minute. Pumping from this caisson was maintained continuously, using the intakes provided in the permanent seal to ledge and additional pumping was done from the working chambers of other caissons during the sinking operations and from caisson 16 through intakes constructed in the permanent seal to rock. The total rate from all these pumps has averaged about 3,200 gallons per minute. The natural slope of the original bed, of the brook flowing past the site from Morton Pond about 1,200 feet upstream, is about 1.5 feet per thousand. The ground water level has been lowered as follows:

Location	To Nov. 30, 1932	Year ending Nov. 30, 1933	Total
At Core Wall (Caisson 13)	41 ft.	55 ft.	96 ft.
220 ft. upstream	27 ft.	28 ft.	55 ft.
800 ft. upstream	17 ft.	20 ft.	37 ft.
2,350 ft. upstream	2 ft.	16 ft.	18 ft.
Morton Pond (lowered by the underdraining operations)	2 ft.	6 ft.	8 ft.
1,050 ft. downstream	11 ft.	24 ft.	35 ft.
2,050 ft. downstream	2 ft.	12 ft.	14 ft.

The contractor is paid for caisson excavation at bid prices for the yardage between fixed elevations, independent of the air pressure required, and is paid for pumping not at a bid price but at a fixed price of 10 cents per million-foot gallons.

The first caisson, No. 18, the steel shoe of which was set March 22, was started at an elevation just above the original brook level and was sunk to a depth of 48 feet before it was necessary to add the air locks. The contractor then continued first with the caissons in the east half of the valley, sinking first every alternate caisson and later the intermediate ones. Each caisson was sunk by open excavation as deep as possible, then under air to sound rock. Then underpinning was placed, the rock cleaned and the caisson sealed against the water pressure by filling the working chamber to a height of 3.5 feet above the cutting edge, leaving the remaining concrete in the chamber to be poured after the completion of grouting operations. In each case the underpinning and sealing to rock was started at the uphill

end of the caisson and extended a little more than half the length of the caisson, the seal not being completed until the next adjoining caisson on the lower or downhill side had been seated on sound ledge. By this method the rock was thoroughly cleaned and the concrete seal carried through to the adjoining caisson, thus simplifying the work of filling the bottoms of the end joints between caissons.

The contractor was permitted to place three more caissons than originally planned, two on the east and one on the west end, in lieu of extending the core wall in sheeted trench excavation. At the end of the year all caissons had been started. Sixteen caissons, in addition to the exploratory caisson, were sunk to bed rock and sealed, except for grouting. 1,819 feet of sinking below the ordered bottom of the open-cut trench or 85% of the estimated total was completed, of which 1,472 feet was by open excavation and 347 feet under compressed air. The average rate of sinking in the open was 8.63 feet in twenty-four hours and under air 2.51 feet. The ground water was lowered to such an extent that although the maximum depth of sinking below the original ground water level was 127 feet, a pressure in excess of 18 lbs. per square inch was exceeded but once, namely, for three days, in caisson 16, which was sunk in advance of the lowering of the ground water level to such an extent that the maximum pressure was 22 lbs. Caisson 14, adjacent to the exploratory caisson, was sealed to ledge under 16 lbs., 32 lbs. less than was required for the sinking of the exploratory caisson under Contract 32 when the only means available for lowering the water level was by pumping from an open sheeted sump about 100 feet from the caisson.

After two adjacent caissons were sealed to ledge, the end joints between them were excavated by sheeting across the gap down to the water level and filling the gap with concrete. Ten of these end joints were completed on the easterly end of the core wall entirely by open excavation. The two joints between caissons 13 and 14 and between 14 and 15 required, in order to reach the bottom, the installation of small air locks, on top of a 3-foot shaft left in the joint which had previously been excavated and concreted to ground water level. To complete the easterly end a short length of core wall was constructed in open trench and a concrete mat 20 feet wide was placed on the ledge for a further distance of 95 feet, the limit of work required under this contract. Grout holes were drilled in general about 8 feet apart and extended 15 feet into the ledge and grouting was done under pressures not exceeding 15 lbs. At the end of the year grouting under the blanket at the east end was completed and drilling and grouting through the sealed caissons into bed rock was in progress.

Aggregates for concrete were obtained from a gravel deposit on land of the Commonwealth about one mile downstream from the site and hauled by truck to a central plant located immediately below the dike site. Here it was crushed, screened, washed and stored for use in batching. Bulk cement was hauled to this plant from the railroad siding at West Ware. Two 5-cubic yard transit mixers received the aggregate, cement and water, weighed and measured at the batching plant, and mixed the concrete en route to the caissons where the concrete was placed in steel forms by a crane and bucket. The forms were erected in 8-foot lifts and two lifts of about 210 cubic yards were poured daily. At the end of the year about 94% of the caisson concrete was poured.

An engineering office was constructed just downstream from the site in a location which will satisfactorily serve the work to be done under other contracts in the construction of the dike embankment and this office will be retained by the Commission for such future use.

The value of work included in contract estimates to November 20, the date of the latest estimate, was $673,814.95, of which 90% was approved for payment. The contractor's force averaged 159 men, the maximum being 313 on May 23. The average number of persons occupying the camp was thirty-four, the maximum population being fifty during the week ending May 15.

The principal items of plant were as follows:

3 Gasoline shovels
3 Traveling cranes, 2 gasoline and 1 Diesel
2 Bulldozers
2 14-ton gasoline rollers
1 Crushing, screening and washing plant

Contract 36. — Dike Core Wall, in the Working Chamber of Caisson 28.

Contract 36. — Dike Core Wall, General View of Caisson Sinking East of the Exploratory Caisson Number 13 in Foreground which was Sunk under Contract 32. Top of Future Dike Embankment indicated by Batter Boards on Hill at Left. Transmission Line Towers in Background Removed under Contract 40.

1 Aggremeter
2 5-cubic yard transit mixers
3 Low pressure air compressors, total capacity 2,550 cu. ft. per min.
1 High pressure air compressor, total capacity 500 cu. ft. per min.
32 Ft. height of steel caisson forms

2 Man locks
4 Muck locks
1 Hospital lock
10 Pumps, each 800 gals. per min. at 90 ft. head
1 Service pump, 100 gals. per min. at 197 ft. head
Trucks, hoists, portable compressor, etc.

The total work done and materials furnished to date under the principal items of Contract 36 are as follows:

Earth excavation in open cut to elevation 400	222,200 cu. yds.
Earth excavation in open cut below elevation 400	47,500 " "
Rock excavation as boulders in open cut	1,428 " "
Rock excavation as ledge in open cut	1,790 " "
Stripping	58,800 " "
Unconsolidated embankment	29,000 " "
Consolidated pervious embankment	202,100 " "
Rolled impervious embankment	3,450 " "
Pumping	119,200 mil.-ft.-gals.
Earth excavation for core wall, bottom of open cut to elevation 310	25,670 cu. yds.
Earth excavation for core wall below elevation 310	480 " "
Rock excavation in caissons to elevation 310	1,584 " "
Rock excavation in caissons below elevation 310	348 " "
Concrete not placed under air pressure	32,464 " "
Concrete placed under air pressure	1,830 " "
Portland cement	55,100 bbls.

Contract 37. — Contract 37, for the purchase of electricity to continue pumping operations begun under Contract 32 at the dike site in Enfield, was continued to completion. Electric power was supplied to continue the operation of pumps which had been installed in the exploratory caisson at the dike for the purpose of lowering the ground water prior to work to be done under Contract 36. Contract 37 was terminated January 21, at which time the West Construction Company took over the maintenance of pumping in the exploratory caisson in accordance with the terms of Contract 36.

During the year a total of 71,900 kilowatt hours were furnished, making the total during the contract 167,400 kilowatt hours. The cost of electricity furnished during the year was $1,438, making the total cost from September 21, 1932, to January 21, $3,348.

Contract 40. — Contract 40, for the removal and relocation of transmission and telephone lines and substation, in the towns of New Salem, Belchertown, Enfield and Ware, was executed June 20 with the New England Power Company and the Central Massachusetts Electric Company. Work was started July 10. Material from the old line was salvaged and used as far as possible in the relocated line. After clearing the new right of way and erecting all the required new towers the two 66,000-volt circuits were killed, the towers dismantled and re-erected in the relocated line and the copper in the old line salvaged. One 66,000-volt circuit was first strung on the new towers and energized October 27. The new substation in Belchertown was then completed and the second high tension line strung and a portion of it energized at 22,000-volts to maintain local service to Enfield and Belchertown while the old 22,000-volt line was being relocated. Finally the local service was carried on the relocated 22,000-volt line and the second 66,000-volt circuit was energized. The new 22,000-volt substation in Belchertown was put into active service November 12. Only preliminary work on the raising of the 110,000-volt line in New Salem was done. At the end of the year the contract was about 90% completed.

The value of work included in contract estimates to November 17, the date of the latest estimate, was $68,046.10. The contractor's force averaged eighty men, the maximum force being 124 on October 6.

Contract 41. — Bids were opened July 18 for constructing a portion of the Belchertown-Pelham highway in the towns of Belchertown and Pelham, Hampshire County. Fourteen bids were received ranging from $222,335.50 to $356,680.30. The contract was executed July 20, with Carlo Bianchi and Company, Inc., Framingham, the low bidder. The Department of Public Works is cooperating in the

construction of this new state highway, paying a portion of the cost, namely, the cost of surfacing, guard rails and traffic signal ducts.

This contract is for 9.1 miles of bituminous macadam highway extending from a point 0.6-mile north of Belchertown Center to the Pelham-Shutesbury line, being the southern portion of the new west highway from Belchertown through New Salem, previously described. Work was started July 26. At the end of the year the grading, drainage, gravel base and bituminous macadam surface was practically completed for a distance of about 3⅓ miles at the Belchertown end, and about ¼-mile north of the Belchertown line in Pelham. Grading of the sub-base was completed for a distance of about 2 miles in Pelham and for about 50% of the remaining distance to the upper end of the contract at the Pelham-Shutesbury line. About 80% of the required drainage was installed. Of the larger concrete structures, one 4′ x 6′ cattle pass and one 8′ x 4′ box culvert were completed. Work of placing broken stone, which was delivered by truck from a quarry in Amherst, was started September 16, and finished for the season October 27. Stone was laid in two courses, a bottom course being 4 inches thick bound by sand, and a top course 2½ inches thick penetrated and sealed with asphalt. Asphalt penetration was started September 27 and completed for the season November 3. Inspection of the stone surfacing and asphalt applications was made by the District Engineer's Office of the Department of Public Works.

At the end of the year the work was about 50% completed.

The value of work included in contract estimates to November 29, the date of the latest estimate, was $98,795.15, of which $35,664 was assumed by the Department of Public Works, covering surfacing items. Of the remaining $63,131.15, 85% was approved for payment. The contractor's force averaged eighty-six men, the maximum being 133 on October 20.

The principal items of plant were as follows:

6 Shovels, steam and gasoline
5 Bulldozers
4 Road rollers
2 Road graders
An average of 14 trucks, 5 to 7½-tons.

Contract 43. — Bids were opened August 11, for constructing an extension of the Belchertown-Pelham highway to New Salem Center in the towns of Shutesbury and New Salem, Franklin County. Seven bids were received ranging from $276,407.00 to $379,772.50. The contract was executed August 25, with V. Barletta Company, Roslindale, for $300,397.50. The Department of Public Works is cooperating in the construction of this new state highway, paying a portion of the cost, namely, the cost of surfacing, guard rails and traffic signal ducts.

This contract is for 7.6 miles of bituminous macadam highway extending from the Pelham-Shutesbury line to a point just north of New Salem Center, being the central portion of the new west highway from Belchertown through New Salem, previously described. The work of clearing was started August 29. Excavation for grading was started September 1, and during the month of September, five shovels were placed on the work. In October, two more shovels were added and rapid progress made on the work of excavation. At the end of the year about 55% of the excavation was completed and grading was completed for a distance of about 4 1/6 miles, extending through Cooleyville from the Prescott-Shutesbury highway in Shutesbury to a point about 1½ miles south of New Salem Center. About 75% of the drainage through the areas of fill was completed. Six inches of gravel sub-base has been placed at various points for a total distance of about 1⅓ miles.

The value of work included in contract estimates to November 25, the date of the latest estimate, was $65,053.50, of which 85% was approved for payment. The contractor's force averaged thirty-six men, the maximum being seventy on September 16.

The principal items of plant were as follows:

7 Gasoline shovels
4 Bulldozers

Contract 44. — Bids were opened November 10, for constructing an extension of the Belchertown-Pelham highway north of New Salem Center in the towns of New Salem and Orange, Franklin County. Nine bids were received ranging from

$179,480.50 to $238,577.00. The contract was executed November 15, with John Iafolla Construction Company, Dedham, the low bidder. The Department of Public Works is cooperating in the construction of this new state highway, paying a portion of the cost, namely, the cost of surfacing, guard rails and traffic signal ducts.

This contract is for 4.1 miles of bituminous macadam highway extending from a point just north of New Salem Center to a point near the Orange-Millington highway about 1,400 feet north of the New Salem-Orange line, being the northern portion of the new west highway from Belchertown through New Salem, previously described. The work of clearing was started November 22 and about 1¾ miles was cleared at the end of the year. No estimates for payment were made. The contractor's force averaged twenty-eight men, the maximum being fifty on November 24.

The principal items of plant were as follows:

2 Gasoline shovels
1 Bulldozer
3 Stone spreaders
2 Road rollers

Geological Data

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State." Such information is being prepared for publication in a subsequent report.

List of Drawings and Tables Appended Hereto

Location of Real Estate Acquired for Quabbin Reservoir.
Takings of Real Estate (and Water Rights).
Status of Contracts Completed between Nov. 30, 1932, and Nov. 30, 1933; and in Force on November 30, 1933.
Canvass of Bids: Contract 36.

For data on Contracts Completed Prior to Nov. 30, 1932, see Sixth and Seventh Annual Reports. A General Plan of the Metropolitan Water Supply and plans and profile of the Quabbin Aqueduct Tunnel have been published in previous reports.

Respectfully submitted,

Frank E. Winsor, *Chief Engineer.*

20 Somerset Street, Boston, Mass.
December 15, 1933.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
Administration, *Commissioners' Office:*		
Salaries, Commissioners	$9,716.66	$76,329.46
Salaries, Clerical	11,763.24	72,709.48
General Legal Expense	0.00	1,377.80
Furniture and Fixtures	295.59	2,458.37
Rent and Upkeep	2,195.52	15,912.39
Automobile Purchase	476.00	2,464.90
Automobile Maintenance	297.46	2,224.48
Miscellaneous Expense (undistributed)	964.88	11,010.87
Advertising	612.48	5,656.00
Printing and Blueprinting	1,647.24	7,070.01
Stationery and Office Supplies	287.78	1,599.95
Postage	209.20	812.25
Total Administration, Commissioners' Office	$28,466.05	$199,625.96
Engineering, *Headquarters' Office:*		
Salaries, Engineering	$75,439.83	$547,131.93
Salaries, Clerical	9,189.93	65,268.83
General Consultant Expense	7,540.79	115,154.72
General Legal Expense	0.00	53,160.29
Furniture and Fixtures	1,122.71	13,238.90
Laboratory Equipment	0.00	1,961.00
Laboratory Supplies	0.00	2,071.94
Rental of Equipment	0.00	3,370.02
Engineering Instruments	25.08	1,053.04
Rent and Upkeep of Boston Office	10,327.46	73,282.06
Rent and Upkeep of Springfield Laboratory	0.00	3,950.54
Automobile Purchase	476.00	3,151.60
Automobile Maintenance	297.58	3,113.78
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	707.13	19,433.38
Printing and Blueprinting	412.71	13,056.77
Stationery and Office Supplies	682.78	4,060.20
Postage	229.00	1,333.58
Total Engineering, Headquarters' Office	$106,451.00	$926,097.21

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
UNASSIGNED:		
Unassigned Supplies and Equipment	$–32.09	$572.63
Total Unassigned	$–32.09	$572.63
Total General Overhead	$134,884.96	$1,126,295.80

DISTRIBUTION OF GENERAL OVERHEAD

ADMINISTRATION, *Commissioners' Office:*		
Wachusett-Coldbrook Tunnel	$6,903.41	$69,679.55
Coldbrook-Swift Tunnel	5,005.89	18,183.84
Quabbin Reservoir	8,718.74	78,711.67
Main Dam and Dike	7,838.01	24,360.62
Southern Sudbury Emergency Supply	0.00	8,690.28
Total Administration, Commissioners' Office	$28,466.05	$199,625.96
ENGINEERING, *Headquarters' Office:*		
Wachusett-Coldbrook Tunnel	$25,767.48	$283,791.72
Coldbrook-Swift Tunnel	19,061.98	75,114.84
Quabbin Reservoir	30,815.19	437,560.38
Main Dam and Dike	30,806.35	96,222.30
Southern Sudbury Emergency Supply	0.00	33,407.97
Total Engineering, Headquarters' Office	$106,451.00	$926,097.21

WACHUSETT-COLDBROOK TUNNEL SECTION OF QUABBIN AQUEDUCT, WARE SUPPLY

GENERAL OVERHEAD:		
Administration	$6,903.41	$69,679.55
Engineering	25,767.48	283,791.72
Total General Overhead	$32,670.89	$353,471.27
ENGINEERING:		
Salaries, Engineering and Clerical	$4,439.04	$387,819.58
Consultant Expense	38.20	7,612.36
Labor	359.20	1,791.20
Furniture and Fixtures	0.00	2,240.89
Engineering Instruments	1.86	7,741.67
Rent and Upkeep	2,029.57	14,756.46
Automobile Purchase	1,294.50	11,242.97
Automobile Maintenance	393.64	14,701.73
Contracts for Investigations and Surveys	0.00	18,640.69
Miscellaneous Expense (undistributed)	223.21	8,914.50
Advertising	0.00	6.05
Printing and Blueprinting	100.51	947.65
Stationery and Office Supplies	174.23	2,724.08
Postage	74.80	393.64
Total Engineering	$9,128.76	$479,533.47
REAL ESTATE, *General Construction:*		
Legal and Expert Expense	$155.52	$5,652.66
Consultant Expense	0.00	455.66
Labor	36.00	1,173.30
Miscellaneous Expense (undistributed)	262.65	846.75
Printing and Blueprinting	1.66	45.14

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
Purchases and Settlements	$838.45	$121,539.16
Taxes	179.30	3,080.17
Maintenance of Real Estate	58.95	622.83
Police Protection, Labor	0.00	31.00
Fire Protection, Equipment	0.00	30.97
Special Agents, Salaries	2,296.00	12,949.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	0.00	1,222.50
Automobile Maintenance	349.89	2,124.30
Miscellaneous Expense (undistributed)	179.56	1,201.73
Printing and Blueprinting	18.62	26.51
Stationery and Office Supplies	2.05	5.48
Postage	9.00	21.36
Total Real Estate	$4,387.65	$151,146.19
WARE WATERSHED PROTECTION:		
Salaries, Engineering and Clerical	$21,577.39	$67,443.44
Legal and Expert Expense	3,520.12	13,181.24
Consultant Expense	0.00	763.70
Labor	556.45	8,875.24
Engineering Instruments	126.10	126.10
Contract 27, for Swamp Improvement above Ware River Intake	0.00	4,395.51
Contract 39, for Rutland-Holden Sewer	50,414.17	50,414.17
Automobile Purchase	543.95	543.95
Automobile Maintenance	984.89	1,566.37
Miscellaneous Expense (undistributed)	1,200.14	3,400.97
Printing and Blueprinting	114.02	403.01
Stationery and Office Supplies	56.35	62.35
Installed Equipment	2,112.74	4,159.70
Purchases and Settlements	450,076.04	1,019,178.01
Taxes	5,191.93	17,085.30
Maintenance of Real Estate	7.20	140.01
Total Ware Watershed Protection	$536,481.49	$1,191,739.07
WARE DIVERSION DAMAGES:		
Salaries, Engineering and Clerical	$21,728.78	$70,479.66
Legal and Expert Expense	738.44	2,550.01
Consultant Expense	19,081.39	29,886.84
Labor	32.85	2,206.88
Furniture and Fixtures	23.44	23.44
Laboratory Equipment	14.29	121.15
Laboratory Supplies	56.89	115.91
Engineering Instruments	19.02	511.00
Rental of Equipment	15.50	197.75
Automobile Purchase	145.38	145.38
Automobile Maintenance	1,060.99	2,295.76
Contracts for Investigations and Surveys	0.00	63.27
Materials of Construction	0.00	136.51
Miscellaneous Expense (undistributed)	1,653.00	7,029.20
Printing and Blueprinting	271.27	527.47
Stationery and Office Supplies	18.91	18.91
Postage	.87	6.62
Purchases and Settlements	75,525.00	123,475.00
Total Ware Diversion Damages	$120,386.02	$239,790.76

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Completed Contracts Nos. 4, 8, 10, 12, 14, 17, 18, 19, 22, 24, 25, 26, 28, 29, 31	$0.00	$9,629,739.99
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$–1,312.00	$58,992.23
Temporary Equipment	1,410.00	6,423.60
Labor	947.97	3,086.32
Contracts for Equipment for Surveys	0.00	898.34
Maintenance of Partially Completed Structures	1,279.50	6,289.49
Maintenance of Grounds	223.85	2,255.36
Purchase of Plants, Trees and Shrubbery	216.19	830.82
Rental of Equipment	0.00	7.00
Miscellaneous Expense	17.63	9,453.84
Total	$2,783.14	$88,237.00
Total Wachusett-Coldbrook Tunnel, Ware Supply	$705,837.95	$12,133,657.75
SPECIAL INVESTIGATION — POLLUTION OF WARE AND QUINAPOXET WATERSHEDS (Expenditures under Chapter 66, Resolves of 1931)		
Salaries, Engineering	$0.00	$986.67
Miscellaneous Expense	0.00	1,009.32
Total Special Investigation	$0.00	$1,995.99
COLDBROOK–SWIFT TUNNEL SECTION OF QUABBIN AQUEDUCT		
GENERAL OVERHEAD:		
Administration	$5,005.89	$18,183.84
Engineering	19,061.98	75,114.84
Total General Overhead	$24,067.87	$93,298.68
ENGINEERING:		
Salaries, Engineering and Clerical	$52,862.87	$159,444.07
Consultant Expense	255.90	255.90
Labor	251.80	536.25
Furniture and Fixtures	97.27	762.58
Engineering Instruments	195.52	4,406.97
Rent and Upkeep	1,239.16	7,798.98
Automobile Purchase	0.00	7,427.97
Automobile Maintenance	1,890.05	13,741.91
Contracts for Investigations and Surveys	0.00	13,525.66
Materials of Construction	0.00	2.25
Miscellaneous Expense (undistributed)	1,009.11	6,812.81
Printing and Blueprinting	153.84	639.87
Stationery and Office Supplies	210.68	1,806.05
Postage	86.37	355.66
Total Engineering	$58,252.57	$217,516.93
REAL ESTATE:		
Legal and Expert Expense	$149.85	$3,040.32
Labor	0.00	12.20
Miscellaneous Expense (undistributed)	0.00	27.16
Printing and Blueprinting	0.00	34.87
Postage	0.00	5 68

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
Purchases and Settlements	$4,300.00	$22,325.00
Taxes	167.86	296.51
Maintenance of Real Estate	15.60	24.85
Fire Protection, Equipment	0.00	60.86
Total Real Estate	$4,633.31	$25,827.45
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 20, Construction of Coldbrook-Swift Tunnel	$1,397,020.68	$3,637,492.50
Total Contracts	$1,397,020.68	$3,637,492.50
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$0.00	$64.75
Installed Equipment	0.00	91.87
Miscellaneous Expense	1,040.85	1,274.29
Total	$1,040.85	$1,430.91
Total Coldbrook-Swift Tunnel	$1,485,015.28	$3,975,566.47

QUABBIN RESERVOIR EXCEPT MAIN DAM AND DIKE

GENERAL OVERHEAD:		
Administration	$8,718.74	$78,711.67
Engineering	30,815.19	437,560.38
Total General Overhead	$39,533.93	$516,272.05
ENGINEERING:		
Salaries, Engineering and Clerical	$10,752.02	$282,468.11
Labor	1,075.20	5,535.99
Furniture and Fixtures	16.41	2,957.38
Laboratory Equipment	218.46	477.40
Laboratory Supplies	615.34	921.48
Rental of Equipment	0.00	16.75
Engineering Instruments	107.66	6,274.90
Rent and Upkeep	1,233.91	5,289.55
Automobile Purchase	4,190.29	16,836.39
Automobile Maintenance	719.33	11,792.53
Special Experiments	30.40	422.80
Contracts for Investigations and Surveys	0.00	10,594.79
Office Buildings	79.63	4,915.54
Miscellaneous Expense (undistributed)	396.19	4,132.66
Printing and Blueprinting	332.17	1,550.38
Stationery and Office Supplies	523.10	4,451.21
Postage	185.25	699.64
Total Engineering	$20,475.36	$359,337.50
REAL ESTATE:		
Legal and Expert Expense	$14,368.48	$132,800.30
Labor	24.00	95.35
Furniture and Fixtures	0.00	15.68
Miscellaneous Expense (undistributed)	962.37	4,861.85
Advertising	0.00	208.66
Printing and Blueprinting	397.15	1,103.37
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	388,051.52	5,470,303.50

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
Taxes	$60,851.19	$185,754.36
Maintenance of Real Estate	1,599.82	3,155.35
Water Supply System	0.00	16.00
Fire Protection, Equipment	31.36	3,467.22
Automobile Purchase	0.00	771.69
Automobile Maintenance	19.29	242.14
Labor	21.20	27.20
Miscellaneous Expense	14.88	107.30
Police Protection, Labor	4.00	14.00
Special Agents, Salaries	2,296.00	13,297.33
Equipment	0.00	118.33
Automobile Purchase	0.00	1,236.96
Automobile Maintenance	337.45	2,354.51
Miscellaneous Expense (undistributed)	144.29	943.38
Printing and Blueprinting	0.00	41.60
Stationery and Office Supplies	1.01	9.33
Postage	.90	11.22
Renting Agents, Salaries	2,632.00	15,467.43
Furniture and Fixtures	0.00	29.29
Miscellaneous Expense (undistributed)	37.69	423.71
Printing and Blueprinting	18.62	18.62
Stationery and Office Supplies	10.00	26.08
Postage	63.23	85.52
Payments to Towns	4,500.00	10,500.00
Total Real Estate	$476,386.45	$5,847,507.73
Quabbin Reservoir Damages:		
Salaries, Engineering	$0.00	$48.68
Legal and Expert Expense	49.02	980.02
Board of Referees	9.75	9.75
Consultant Expense	715.45	2,158.82
Miscellaneous Expense	5.90	18.15
Purchases and Settlements	1,425.00	45,285.00
Total Quabbin Reservoir Damages	$2,205.12	$48,500.42
Swift Diversion Damages:		
Salaries, Engineering and Clerical	$11,833.22	$55,352.83
Legal and Expert Expense	970.50	4,278.62
Consultant Expense	22,495.02	49,597.77
Labor	0.00	73.70
Furniture and Fixtures	30.96	30.96
Laboratory Equipment	128.58	705.93
Laboratory Supplies	508.87	809.37
Engineering Instruments	171.17	732.20
Rental of Equipment	1.50	10.50
Automobile Purchase	1,308.41	1,308.41
Automobile Maintenance	1,106.47	1,413.26
Contracts for Investigations and Surveys	0.00	569.47
Materials of Construction	0.00	18.99
Miscellaneous Expense (undistributed)	394.34	5,378.92
Printing and Blueprinting	197.43	583.33
Stationery and Office Supplies	20.75	20.75
Purchases and Settlements	364,725.00	567,225.00
Total Swift Diversion Damages	$403,892.22	$688,110.01

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
Quabbin Reservoir — Cemeteries		
Quabbin Park Cemetery Construction:		
Salaries, Engineering and Clerical	$340.99	$10,705.43
Legal and Expert Expense	0.00	65.00
Consultant Expense	0.00	125.00
(Construction) Labor	1,219.38	8,600.91
Tools and Equipment	1.63	83.96
Automobile Purchase	0.00	1,615.37
Automobile Maintenance	449.19	982.61
Rental of Equipment	0.00	33.19
Purchases and Settlements	4,000.00	8,850.00
Construction Materials	142.90	1,465.53
Purchase and Planting of Trees and Shrubbery	63.33	218.93
Receiving Vault	0.00	2,768.85
Water Supply System	2.00	1,251.97
Maintenance of Grounds	761.53	1,831.23
Miscellaneous Expense (undistributed)	15.97	155.01
Printing and Blueprinting	7.17	157.58
Stationery and Office Supplies	5.52	9.03
Contract 34, Construction of Driveways	0.00	7,842.94
Sub Total Quabbin Park Cemetery Construction	$7,009.61	$46,762.54
Removals from Cemeteries within Reservoir Area to Quabbin Park Cemetery:		
Salaries, Engineering and Clerical	$2,669.79	$2,839.34
Tools and Equipment	147.88	412.14
Automobile Purchase	0.00	2,669.99
Automobile Maintenance	382.60	384.05
Removal and Reinterment of Bodies	3,774.59	4,313.28
Removal and Resetting of Monuments	2,786.46	2,950.86
Miscellaneous Expense	0.00	2.00
Rental of Equipment	10.50	10.50
Sub Total Removals to Quabbin Park Cemetery	$9,771.82	$13,582.16
Removals from Cemeteries within Reservoir Area to Cemeteries other than Quabbin Park:		
Salaries, Engineering and Clerical	$750.80	$5,646.16
Automobile Purchase	0.00	380.00
Automobile Maintenance	47.29	62.09
Purchases and Settlements	985.50	6,645.10
Perpetual Care Fund Contributions	0.00	100.00
Removal and Reinterment of Bodies	652.80	5,887.75
Removal and Resetting of Monuments	760.83	5,420.02
Miscellaneous Expense	0.00	117.91
Sub Total Removals to Other Cemeteries	$3,197.22	$24,259.03
Total Quabbin Reservoir Cemeteries	$19,978.65	$84,603.73
Permanent Construction — Except Construction Contracts:		
Installed Equipment	$0.00	$214.78
Total	$0.00	$214.78

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
HIGHWAY AND PUBLIC UTILITY RELOCATION:		
Salaries, Engineering and Clerical	$47,093.84	$95,564.43
Legal and Expert Expense	0.00	49.10
Consultant Expense	8,449.40	8,449.40
Labor	1,640.31	1,882.01
Furniture and Fixtures	61.74	61.74
Contract No. 21, Construction of about 5.2 miles of the Ware-Belchertown Highway	5,000.00	129,980.25
Contract No. 40, Removal and Relocation of Transmission and Telephone Lines and Substation of the New England Power Co. and Central Massachusetts Electric Co.	68,046.10	68,046.10
Contract 41, Construction of about 9.1 miles of the Belchertown-Pelham Highway in Belchertown and Pelham	53,661.48	53,661.48
Contract 43, Construction of about 7.6 miles of Extension of Belchertown-Pelham Highway in Shutesbury and New Salem to New Salem Center	55,295.48	55,295.48
Installed Equipment	319.63	417.45
Temporary Equipment	0.00	149.50
Engineering Instruments	266.91	433.68
Automobile Purchase	0.00	535.00
Automobile Maintenance	1,422.21	2,472.68
Miscellaneous Expense (undistributed)	866.46	1,443.12
Printing and Blueprinting	182.83	202.22
Stationery and Office Supplies	23.83	83.40
Total Highway and Public Utility Relocation	$242,330.22	$418,727.04
Total Quabbin Reservoir, Except Main Dam and Dike	$1,204,801.95	$7,963,273.26

QUABBIN RESERVOIR MAIN DAM AND DIKE

GENERAL OVERHEAD:		
Administration	$7,838.01	$24,360.62
Engineering	$30,806.35	96,222.30
Total General Overhead	$38,644.36	$120,582.92
ENGINEERING:		
Salaries, Engineering and Clerical	$41,623.00	$105,613.38
Consultant Expense	724.30	8,295.52
Labor	4,132.60	5,140.00
Furniture and Fixtures	127.22	191.40
Laboratory Equipment	0.00	759.77
Rental of Equipment	911.00	1,341.50
Engineering Instruments	3.27	149.09
Rent and Upkeep	28.90	44.90
Automobile Maintenance	875.28	1,435.91
Contracts for Investigations and Surveys	10,817.92	60,802.38
Special Experiments	1,313.42	1,313.42
Water Supply System	10.00	10.00
Miscellaneous Expense (undistributed)	6,662.91	8,563.86
Printing and Blueprinting	129.19	505.81
Stationery and Office Supplies	54.12	199.17
Total Engineering	$67,413.13	$194,366.11

	Year ending Nov. 30, 1933	Total to Nov. 30, 1933
PERMANENT CONSTRUCTION-CONSTRUCTION CONTRACTS:		
Contract No. 30, Constructing Stream Control Works at Main Dam	$120,274.87	$544,610.60
Contract No. 32, Constructing Exploratory Caissons at Main Dam and Dike	0.00	162,838.33
Contract No. 36, Constructing a Core Wall to Sound Rock at the Site of the Dike	606,433.45	606,433.45
Total Contracts	$726,708.32	$1,313,882.38
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$0.00	$2,519.40
Installed Equipment	0.00	3,253.00
Temporary Equipment	0.00	1,549.81
Miscellaneous Expense	1,164.65	2,260.66
Total	$1,164.65	$9,582.87
Total Quabbin Reservoir Main Dam and Dike	$833,930.46	$1,638,414.28
SOUTHERN SUDBURY EMERGENCY SUPPLY		
GENERAL OVERHEAD:	$0.00	$42,098.25
ENGINEERING:	0.00	44,235.07
REAL ESTATE:		
Legal and Expert Expense	29.61	2,251.21
Consultant Expense	0.00	116.87
Printing and Blueprinting	0.00	4.28
Purchases and Settlements	25.00	27,788.22
Taxes	0.00	392.60
Total Real Estate	$54.61	$30,553.18
SOUTHERN SUDBURY DIVERSION DAMAGES	$0.00	$50,752.66
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS		
Completed Contracts Nos. 6, 7, 11, 13, 15, 16	0.00	375,194.44
Contract No. 5, Cordaville Pipe Line	0.00	83,262.86
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS	0.00	11,937.37
Total Southern Sudbury Emergency Supply	$54.61	$638,033.83
SUMMARY		
Wachusett-Coldbrook Tunnel, Ware Supply	$705,837.95	$12,133,657.75
Special Investigation — Pollution of Ware and Quinapoxet Watersheds	0.00	1,995.99
Coldbrook-Swift Tunnel	1,485,015.28	3,975,566.47
Quabbin Reservoir Except Main Dam and Dike	1,204,801.95	7,963,273.26
Quabbin Reservoir Main Dam and Dike	833,930.46	1,638,414.28
Southern Sudbury Emergency Supply	54.61	638,033.83
Unassigned	−32.09	572.63
Grand Total	$4,229,608.16	$26,351,514.21
RECEIPTS FROM RENTS, SALES, ETC.		
Sales	$7,448.82	$115,773.31
Rents	49,584.55	253,991.75
Miscellaneous	251.65	3,171.64
Total Receipts	$57,285.02	$372,936.70

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE QUABBIN RESERVOIR

(TITLE VESTED IN COMMONWEALTH)

TOWNS	TOTAL – NOV. 30, 1932. 1932 ANNUAL REPORT (ACRES)	TOTAL – NOV. 30, 1932. REVISED-SEE NOTE (ACRES)*	TOTAL FOR YEAR ENDING NOV. 30, 1933 (ACRES)	TOTAL NOV. 30, 1933 (ACRES)	REMARKS
BELCHERTOWN	1,663	1,663	946	2,609	
DANA	7,487	7,480	406	7,886	
ENFIELD	7,057	7,057	638	7,695	
GREENWICH	9,535	9,535	388	9,923	
HARDWICK	2,233	2,233	311	2,544	
NEW SALEM	6,318	6,318	347	6,665	
PELHAM	2,691	2,691	1,518	4,209	
PETERSHAM	761	686**	—	686	
PRESCOTT	8,983	8,991	756	9,747	
SHUTESBURY	1,518	1,521	141	1,662	
WARE	460	464	181	645	
WENDELL	36	36	—	36	
TOTALS	48,742	48,675	5,632	54,307	

* Revisions have been made using acreages obtained from surveys wherever available, otherwise from deeds, property blanks etc.

** 75 acres were transferred to the Massachusetts Department of Conservation.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TAKINGS OF REAL ESTATE (AND WATER RIGHTS)

TAKING FOR	TAKING NO.	TOWN	COUNTY	DATE OF TAKING	PLAN NO.	TITLE VESTED IN COMMONWEALTH FEE (Acres)	EASEMENT (Acres)
Southern Sudbury Emergency Supply	1 to 9 incl.	Details previously reported. See 1930 Annual Report.			C-1 to C-15 incl.	258.81 (Also Water Rights)	29.02
Wachusett-Coldbrook Tunnel section of Quabbin Aqueduct.	1 to 4 incl.	Details previously reported. See 1930 Annual Report.			T-1 to T-13 incl.	570.22	
Coldbrook-Swift Tunnel section of Quabbin Aqueduct.	1 to 3 incl.	Details previously reported. See 1931 Annual Report. *(391.42 acres of this total are within the Quabbin Res. Area)			T-14 to T-27 incl.	* 544.81	4.06
Quabbin Reservoir (Swift River Reservoir)	1 to 5 incl.	Details previously reported. See 1931 and 1932 Annual Reports.			S-1 to S-9 incl.	431.90	0.39
" " Belchertown-Pelham Hwy.	6	Belchertown Pelham	Hampshire	July 11, 1933	S-10 to S-14 incl.	25.79 38.46	0.28 0.11
" " " " " Extension	10	Shutesbury New Salem	Franklin	Aug. 11, 1933	S-18 to S-23 incl.	31.55 41.58	1.46 2.07
" " " " " "	12	New Salem Orange	Franklin	Nov. 14, 1933	S-25 to S-27 incl.	34.21 1.92	2.94
" " Transmission Line Relocation.	7	Enfield	Hampshire	July 11, 1933	S-16		5.03
" " " " "	8	"	"	July 25, 1933	S-15		4.28
" " " " "	9	Ware	"	July 25, 1933	S-17		.55
" " " " "	11	"	"	Aug. 11, 1933	S-24		2.74
						605.41	19.85
Ware River Watershed. - Real Estate " " " - Diversion of Flood Waters	1	Details previously reported. See 1932 Annual Report.			W-1 No Plan	0.25 Water	Rights
" " " - Rutland Holden Sewer	2	Holden Rutland	Worcester	July 11, 1933	A-1 to A-14 incl.		18.55 4.39
						0.25	22.94

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED BETWEEN NOV. 30, 1932 AND NOV. 30, 1933

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
30	Stream Control Works at Main Dam – Quabbin Reservoir.	Belchertown, Enfield and Ware.	Swift	Northern States Contracting Co.	July 17, 1931	19	July 21, 1931	$560,922.50	$544,610.60	Aug. 29, 1933
37	Purchase of Power at Dike Site	Enfield.	Swift	New England Power Co.	Date of Agreement = Sept. 21, 1932			Agreed Rates	3,348.00	Feb. 1, 1933

STATUS OF CONTRACTS IN FORCE ON NOV. 30, 1933

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	PAYMENTS TO DATE
20	Coldbrook-Swift Tunnel.	Barre, Hardwick and Greenwich	Swift	Wenzel & Henoch, Construction Co.	Mar. 27, 1931	13	April 10, 1931	$4,978,031.80	$3,637,492.50
23	Making Borings.	Belchertown, Ware, Enfield, Greenwich & Hardwick	Swift	Sprague & Henwood Inc.	Nov. 5, 1929	6	Nov. 5, 1929	10,950.00	38,513.84
33	Purchase of Power at Shaft 1.	West Boylston	Ware	New England Power Co.	Date of Agreement = Aug. 6. 1931			Agreed Rates	1,611.63
35	Purchase of Power at Dam Site.	Enfield	Swift	New England Power Co.	Date of Agreement = June 2, 1932			Agreed Rates	2,659.10
36	Core Wall to Sound Bed Rock at Dike Site.	Enfield & Ware	Swift	West Construction Co.	Dec. 9, 1932	25	Dec. 28, 1932	999,265.00	606,433.45
39	Construction of Trunk Sewer.	Rutland & Holden	Ware	James J. Coughlan & Sons, Inc.	July 7, 1933	21	July 11, 1933	184,327.50	50,414.17
40	Removal and Relocation of Transmission and Telephone Lines & Sub-Station.	New Salem, Belchertown, Enfield & Ware	Swift	New England Power Company & Central Massachusetts Electric Company	Date of Agreement = June 20, 1933			Actual Cost	68,046.10
41	Construction of Portion of Belchertown – Pelham Highway.	Belchertown & Pelham	Swift	Carlo Bianchi Co., Inc.	July 18, 1933	14	July 19, 1933	222,335.50	** 83,975.88
42	Use of Worcester Sewerage System and Treatment Works % Rutland-Holden Sewer.	Worcester	Ware	City of Worcester	Date of Agreement = May 4, 1933.			Lump Sum = 325,000.00 Annual Charge = *	325,000.00 None
43	Construction of Extension of Belchertown Pelham Highway to New Salem Center.	Shutesbury & New Salem	Swift	V. Barletta Co.	Aug. 11, 1933	7	Aug. 22, 1933	300,397.50	55,295.48
44	Construction of Extension of Belchertown Pelham Highway North of New Salem Center.	New Salem & Orange	Swift	John Iafolla Construction Co.	Nov. 10, 1933	9	Nov. 14, 1933	179,480.50	None

* Proportion of Annual Maintenance Cost.
** Of this amount the State Dept. of Public Works paid $30,314.40 for surfacing, guard rail and traffic signal duct items.

Awarded to lowest bidder in each case except Contract 43, awarded to 2nd lowest bidder.

Canvass of Bids for Contract 36 Opened Dec. 9, 1932

Commonwealth of Massachusetts
Metr. Distr. Water Supply Commission

CONTRACT 36

For Constructing a Core Wall to Sound Rock at the Site of the Dike of Quabbin Reservoir in the Towns of Enfield and Ware

Item	Description	Unit	Quantity
1	Earth excavation in open cut to El 400	Cu Yd	225,000
2	" " " " below El 400	Cu Yd	70,000
3	Rock excavation as boulders in open cut	Cu Yd	9500
4	" " " ledge	Cu Yd	300
5	Stripping	Cu Yd	65,000
6	Unconsolidated embankment	Cu Yd	20,000
7	Consolidated pervious embankment	Cu Yd	260,000
8	Rolled impervious embankment	Cu Yd	160,000
9	Gravel surfacing	Cu Yd	4,000
10	Brook diversion	Lump Sum	
11	Pumping (Unit fixed price)	M.H.G.	250,000
12	Observation pipe wells	Lin Ft	1,000
13	Earth excav. core wall, bot. of open cut to El 310	Cu Yd	30,000
14	" " " below El 310	Cu Yd	3,000
15	Rock excavation in caissons to El 310	Cu Yd	2,000
16	" " " below El 310	Cu Yd	700
17	Rock excav. core wall below bot. open cut outside caisson	Cu Yd	200
18	Preparing rock surface in caissons above El 310	Sq Yd	600
19	" " " below El 310	Sq Yd	700
20	" " " outside caisson limits	Sq Yd	400
21	Concrete, not placed under air pressure	Cu Yd	42,000
22	Concrete placed under air pressure	Cu Yd	7,500
23	Impervious filling in caissons	Cu Yd	4,000
24	Imper. fill core wall below bot. open cut outside caisson	Cu Yd	600
25	Drilling holes in rock or masonry	Lin Ft	7,000
26	Furnishing and placing grout	Cu Yd	1,000
27	Portland cement	Bbl.	85,000
28	Riprap	Cu Yd	6,000
29	Cobble gutters	Sq Yd	2,500
30	Guard rail	Lin Ft	2,600
31	Pipe culverts	Lin Ft	500
32	Engineers office	Lump Sum	
33	Cleaning up	Lump Sum	
	Totals		

Item	(1) ★ West Construction Company, 80 State St, Boston, Mass. Price	Amount	(2) C. & R. Construction Co., 75 Bradeen St., Roslindale, Mass. Price	Amount	(3) J. F. Fitzgerald Construction Co., 38 Chauncy St, Boston, Mass. Price	Amount	(4) Brader Construction Corporation, 551 Fifth Avenue, New York, N.Y. Price	Amount
1	$ .19	$42,750	$ .50	$112,500	$ .22	$49,500	$ .30	$67,500
2	.20	14,000	.50	35,000	.34	23,800	.30	21,000
3	.50	4,750	.50	4,750	.68	6,460	.30	2,850
4	8	2,400	3	900	4.00	1,200	5	1,500
5	.20	13,000	.45	29,250	.52	33,800	.30	19,500
6	.10	2,000	.10	2,000	.03	600	.07	1,400
7	.12	31,200	.05	13,000	.11	28,600	.07	18,200
8	.36	57,600	.25	40,000	.18	28,800	.30	48,000
9	.45	1,800	.25	1,000	.70	2,800	2.50	10,000
10	5600	5,600	15,000	15,000	8919	8,919	10,000	10,000
11	.10	25,000	.10	25,000	.10	25,000	.10	25,000
12	2.50	2,500	3.50	3,500	2.65	2,650	6	6,000
13	5.85	175,500	6.50	195,000	8.72	261,600	11	330,000
14	13	39,000	6.50	19,500	17.32	51,960	11	33,000
15	9	18,000	1	2,000	30.	60,000	12	24,000
16	14	9,800	1	700	40	28,000	12	8,400
17	8	1,600	10	2,000	10	2,000	12	2,400
18	2	1,200	2	1,200	5	3,000	1.20	720
19	5	3,500	2	1,400	6	4,200	1.20	840
20	1	400	2	800	1	400	1.20	480
21	5.60	235,200	7	294,000	5.05	212,100	7.15	300,300
22	5.50	41,250	4	30,000	6.22	46,650	7.15	53,625
23	1	4,000	1	4,000	.20	800	.15	600
24	.65	390	1	600	1	600	.15	90
25	1	7,000	.75	5,250	2	14,000	.40	2,800
26	7.00	7,000	8	8,000	10	10,000	5	5,000
27	2.70	229,500	2.20	187,000	2.38	202,300	2.25	191,250
28	2.50	15,000	.50	3,000	2	12,000	1.50	9,000
29	.65	1,625	.50	1,250	1.75	4,375	1	2,500
30	.50	1,300	.45	1,170	.35	910	.40	1,040
31	2.50	1,250	1.65	825	1.75	875	3	1,500
32	3,150	3,150	5000	5,000	2,800	2,800	5,000	5,000
33	1,000	1,000	1000	1,000	2556	2,556	7,000	7,000
Totals		$999,765		$1,055,595		$1,193,265		$1,210,465

Item	(5) James J. Coughlan & Sons Inc., 80 Federal St, Boston, Mass. Price	Amount	(6) Nicholas Di Menna, 645 E. Tremont Av., New York, N.Y. Price	Amount	(7) Cenedella & Co., 167 Main St, Milford, Mass. Price	Amount	(8) Wenzel & Henoch Const Co., Gilbertville, Mass. Price	Amount
1	$ .26	$58,500	$ .22	$49,500	$ .18	$40,500	$ .18	$40,500
2	.29	20,300	.22	15,400	.26	18,200	.26	18,200
3	1.03	9,785	5	47,500	.60	5,700	2	19,000
4	8.05	2,415	5	1,500	3.60	1,080	7.50	2,250
5	.33	21,450	.23	14,950	.67	43,550	.25	16,250
6	.08	1,600	.20	4,000	.06	1,200	.08	1,600
7	.07	18,200	.20	52,000	.085	22,100	.07	18,200
8	.53	84,800	.20	32,000	.54	86,400	.30	48,000
9	.52	2,080	3	12,000	3.60	14,400	1	4,000
10	3,650	3,650	11,000	11,000	10000	10,000	5400	5,400
11	.10	25,000	.10	25,000	.10	25,000	.10	25,000
12	2.50	2,500	2.50	2,500	2	2,000	4.50	4,500
13	10.30	309,000	5.60	168,000	11.90	357,000	7.84	235,200
14	12	36,000	8	24,000	23	69,000	16.30	48,900
15	11.50	23,000	20	40,000	1	2,000	35	70,000
16	23	16,100	25	17,500	1	700	55	38,500
17	10	2,000	20	4,000	10	2,000	7.50	1,500
18	9	5,400	3	1,800	10	6,000	2	1,200
19	9	6,300	3	2,100	10	7,000	4	2,800
20	4	1,600	1.50	600	4	1,600	1	400
21	6.30	264,600	9	378,000	5	210,000	7.80	327,600
22	6.60	49,500	13	97,500	8.50	63,750	11.50	86,250
23	.60	2,400	.35	1,400	1.25	5,000	1.50	6,000
24	.60	360	.25	150	6	3,600	1	600
25	.50	3,500	2	14,000	2	14,000	1	7,000
26	15	15,000	12	12,000	12	12,000	15	15,000
27	2.50	212,500	2.25	191,250	2.15	182,750	2.30	195,500
28	1.15	6,900	1.50	9,000	2.40	14,400	2	12,000
29	1.43	3,575	1	2,500	1.80	4,500	1.50	3,750
30	.63	1,638	1	2,600	1.60	4,160	.75	1,950
31	2.55	1,275	1	500	6	3,000	2	1,000
32	3000	3,000	7,000	7,000	15000	15,000	2500	2,500
33	1000	1,000	10,000	10,000	4,000	4,000	500	500
Totals		$1,214,918		$1,251,250		$1,251,590		$1,261,050

Item	(9) Brewster Construction Company, 275 Fort Lee Rd, Bogota, N.J. Price	Amount	(10) Booth & Flinn Company, 1942 Forbes St, Pittsburgh, Pa. Price	Amount	(11) The Carleton Company, Inc, 151 West 42nd St, New York, N.Y. Price	Amount	(12) Northern States Contracting Co, 111 Broadway, Elizabeth N.J. Price	Amount	(13) The Foundation Company, 120 Liberty St, New York, N.Y. Price	Amount
1	$ .20	$45,000	$ .20	$45,000	$ 1.72	$387,000	$ .28	$63,000	$ .20	$45,000
2	.20	14,000	.29	20,300	1.77	123,900	.28	19,600	.30	21,000
3	.55	5,225	1.03	9,785	1.72	16,340	2.07	19,665	1	9,500
4	3.30	990	9	2,700	10	3,000	5.52	1,656	7.50	2,250
5	.25	16,250	.33	21,450	.86	55,900	.35	22,750	.35	22,750
6	.06	1,200	.08	1,600	.09	1,800	.01	200	.07	1,400
7	.08	20,800	.07	18,200	.10	26,000	.07	18,200	.07	18,200
8	.55	88,000	.53	84,800	.30	48,000	.41	65,600	.50	80,000
9	.55	2,200	.52	2,080	.50	2,000	.41	1,640	.50	2,000
10	5,500	5,500	6000	6,000	5900	5,900	3,880	3,880	5000	5,000
11	.10	25,000	.10	25,000	.10	25,000	.10	25,000	.10	25,000
12	1.27	1,270	1	1,000	5.25	5,250	3.10	3,100	3.25	3,250
13	11.70	351,000	13.20	396,000	2.60	78,000	4.39	131,700	8	240,000
14	11.70	35,100	16	48,000	3.60	10,800	11.50	34,500	15	45,000
15	6	12,000	14.30	28,600	4.60	9,200	20.70	41,400	16	32,000
16	6	4,200	18	12,600	18.60	13,020	20.70	14,490	40	28,000
17	6	1,200	8	1,600	15	3,000	11	2,200	10	2,000
18	3.50	2,100	1.30	780	1.60	960	2.07	1,242	6	3,600
19	3.50	2,450	1.50	1,050	1.70	1,190	2.07	1,449	12	8,400
20	.60	240	1.20	480	.50	200	2.07	828	4	1,600
21	7.05	296,100	6.60	277,200	4.25	178,500	10.60	445,200	10.65	447,300
22	8.75	65,625	6.30	47,250	7	52,500	10.60	79,500	4.90	36,750
23	2.85	11,400	1.50	6,000	3	12,000	.83	3,320	1	4,000
24	.70	420	1.50	900	2	1,200	.83	498	1	600
25	1.55	10,850	1.50	10,500	.35	2,450	1.38	9,660	.80	5,600
26	6.75	6,750	7	7,000	2	2,000	13.80	13,800	15	15,000
27	2.52	214,200	2	170,000	2.50	212,500	2.94	249,900	2.50	212,500
28	2.20	13,200	1.15	6,900	.50	3,000	1.66	9,960	1	6,000
29	1.65	4,125	1.43	3,575	.50	1,250	2.76	6,900	1.50	3,750
30	.55	1,430	.63	1,638	.40	1,040	.69	1,794	.60	1,560
31	2.20	1,100	2.35	1,175	2.25	1,125	2.90	1,450	2	1,000
32	2360	2,360	2000	2,000	8,000	8,000	5000	5,000	5000	5,000
33	1400	1,400	2000	2,000	500	500	1300	1,300	1500	1,500
Totals		$1,262,665		$1,263,163		$1,292,925		$1,300,462		$1,936,510

Item	Description	Unit	Quantity
1	Earth excavation in open cut to El 400	Cu Yd	225,000
2	" " " " below El 400	Cu Yd	70,000
3	Rock excavation as boulders in open cut	Cu Yd	9,600
4	" " " ledge	Cu Yd	300
5	Stripping	Cu Yd	65,000
6	Unconsolidated embankment	Cu Yd	20,000
7	Consolidated pervious embankment	Cu Yd	260,000
8	Rolled impervious embankment	Cu Yd	160,000
9	Gravel surfacing	Cu Yd	4,000
10	Brook diversion	Lump Sum	
11	Pumping (Unit fixed price)	M.H.G.	250,000
12	Observation pipe wells	Lin Ft	1,000
13	Earth excav. core wall, bot. of open cut to El 310	Cu Yd	30,000
14	" " " below El 310	Cu Yd	3,000
15	Rock excavation in caissons to El 310	Cu Yd	2,000
16	" " " below El 310	Cu Yd	700
17	Rock excav. core wall below bot. open cut outside caisson	Cu Yd	200
18	Preparing rock surface in caissons above El 310	Sq Yd	600
19	" " " below El 310	Sq Yd	700
20	" " " outside caisson limits	Sq Yd	400
21	Concrete, not placed under air pressure	Cu Yd	42,000
22	Concrete placed under air pressure	Cu Yd	7,500
23	Impervious filling in caissons	Cu Yd	4,000
24	Imper. fill core wall below bot. open cut outside caisson	Cu Yd	600
25	Drilling holes in rock or masonry	Lin Ft	7,000
26	Furnishing and placing grout	Cu Yd	1,000
27	Portland cement	Bbl	85,000
28	Riprap	Cu Yd	6,000
29	Cobble gutters	Sq Yd	2,500
30	Guard rail	Lin Ft	2,600
31	Pipe culverts	Lin Ft	500
32	Engineers office	Lump Sum	
33	Cleaning up	Lump Sum	
	Totals		

Item	(14) George H. Flinn Corporation, 9 East 41st St, New York, N.Y. Price	Amount	(15) Arthur McMullen Co, 50 Church St., New York, N.Y. Price	Amount	(16) The George R. Cooke Co., 1216 Penobscot Bldg, Detroit, Mich. Price	Amount	(17) J. N. Ferguson Co, 289 Chapman St, Providence, R.I. Price	Amount
1	$ .50	$112,500	$ .19	$42,750	$ .23	$51,750	$ .40	$90,000
2	.75	52,500	.22	15,400	.345	24,150	1.22	85,400
3	.85	8,075	.50	4,750	.93	8,835	3	28,500
4	5.50	1,545	2.50	750	6	1,800	3	900
5	.69	44,850	.34	22,100	.23	14,950	.35	22,750
6	.57	11,400	.04	800	.09	1,800	.10	2,000
7	.60	156,000	.06	15,600	.12	31,200	.15	39,000
8	.42	67,200	.44	70,400	.50	80,000	.40	64,000
9	1	4,000	.50	2,000	2	8,000	2	8,000
10	10,000	10,000	3,764	3,764	4000	4,000	7,500	7,500
11	.10	25,000	.10	25,000	.10	25,000	.10	25,000
12	1.40	1,400	3.45	3,450	5	5,000	3.50	3,500
13	9	270,000	14.31	429,300	13	390,000	15.15	454,500
14	12	36,000	24.30	72,900	13	39,000	22.12	66,360
15	5.45	10,900	25.85	51,700	15	30,000	20	40,000
16	16.75	11,725	48.15	33,705	15	10,500	25	17,500
17	7.90	1,580	6.05	1,210	20	4,000	25	5,000
18	2.50	1,500	5.21	3,126	2	1,200	2	1,200
19	2.50	1,750	7.24	5,068	2	1,400	5	3,500
20	1.75	700	1.69	676	2	800	5	2,000
21	5.35	224,700	7.20	302,400	9	378,000	5.21	218,820
22	9.70	72,750	7.80	58,500	9	67,500	7.21	54,075
23	.60	2,400	1.50	6,000	1.50	6,000	2	8,000
24	.60	360	1.50	900	1.50	900	1.50	900
25	1.15	8,050	.88	6,160	3	21,000	1	7,000
26	8.20	8,200	7.50	7,500	20	20,000	15	15,000
27	2.25	191,250	2.36	200,600	2.20	187,000	2.33	198,050
28	.85	5,100	1.25	7,500	1.50	9,000	3	18,000
29	.70	1,750	1.25	3,125	1.50	3,750	1.50	3,750
30	.75	1,950	.50	1,300	.60	1,560	.60	1,560
31	1.70	850	2.25	1,125	2	1,000	2.50	1,250
32	10,000	40,000	5,000	5,000	3,500	3,500	4,000	4,000
33	10,000	10,000	3380	3,380	5,000	5,000	5,500	5,500
Totals		$1,573,005		$1,408,019		$1,437,595		$1,502,515

Item	(18) The Dravo Contracting Co., Dravo Bldg., Pittsburgh, Pa. Price	Amount	(19) Rodgers & Hagerty, Inc, 500 Fifth Ave, New York, N.Y. Price	Amount	(20) Cornell Contracting Corporation, 405 Lexington Ave, New York, N.Y. Price	Amount	(21) Marcus Contracting Co. Inc, 150 Nassau St, New York, N.Y. Price	Amount
1	$ .17	$38,250	$ .60	$135,000	$ .22	$49,500	$ .58	$130,500
2	.22	15,400	.19	13,300	.30	21,000	1.50	105,000
3	.90	8,550	.50	4,750	3	28,500	3	28,500
4	5	1,500	8	2,400	6	1,800	10	3,000
5	.35	22,750	.18	11,700	.70	45,500	.86	55,900
6	.06	1,200	.10	2,000	.40	8,000	.10	2,000
7	.07	18,200	.12	31,200	.45	117,000	.25	65,000
8	.50	80,000	.36	57,600	.70	112,000	.76	121,600
9	.45	1,800	1	4,000	4.50	18,000	3	12,000
10	5,000	5,000	5000	5,000	10,000	10,000	18,950	18,950
11	.10	25,000	.10	25,000	.10	25,000	.10	25,000
12	2	2,000	3	3,000	5	5,000	3	3,000
13	10.75	322,500	20.20	606,000	24	720,000	17.90	537,000
14	24	72,000	20.20	60,600	30	90,000	20	60,000
15	35	70,000	20.20	40,400	22	44,000	20	40,000
16	60	42,000	20.20	14,140	28	19,600	20	14,000
17	6	1,200	8	1,600	10	2,000	10	2,000
18	7.50	4,500	1	600	6	3,600	25	15,000
19	9.50	6,650	1	700	7	4,900	25	17,500
20	2.50	1,000	1	400	3	1,200	25	10,000
21	12	504,000	10.25	430,500	4.50	189,000	7.75	325,500
22	8	60,000	10.25	76,875	7	52,500	8.50	63,750
23	1	4,000	.25	1,000	.70	2,800	.75	3,000
24	2.50	1,500	.25	150	.70	420	.75	450
25	3	21,000	3.50	24,500	1.50	10,500	1.50	10,500
26	10.50	10,500	7	7,000	9	9,000	14	14,000
27	2.50	212,500	2.15	182,750	2.80	238,000	2.19	186,150
28	1.25	7,500	1.25	7,500	2	12,000	3.50	21,000
29	1.50	3,750	1.25	3,125	2.50	6,250	4	10,000
30	.60	1,560	.40	1,040	2.50	6,500	2	5,200
31	2.50	1,250	2.25	1,125	2.50	1,250	5	2,500
32	5000	5,000	5000	5,000	9,000	9,000	2,000	2,000
33	1,000	1,000	100	100	7,000	7,000	15,000	15,000
Totals		$1,573,080		$1,760,055		$1,860,820		$1,925,000

Item	(22) Merritt-Chapman & Scott Corporation, Whitehall Building, 17 Battery Place, New York, N.Y. Price	Amount	(23) Silas Mason Company, Inc, 117 London St, East Boston, Mass. Price	Amount	(24) Spencer & Ross Inc, 710 Book Bldg, Detroit, Mich. Price	Amount	(25) Peter F. Connolly, Myrtle & No. Portland Aves, Brooklyn, N.Y. Price	Amount
1	$ .50	$112,500	$ .30	$67,500	$ 1.15	$258,750	$ .73	$164,250
2	.50	35,000	.45	31,500	1.15	80,500	.74	51,800
3	1	9,500	1.10	10,450	2	19,000	2.48	23,560
4	3	900	12	3,600	10	3,000	9	2,700
5	.50	32,500	1	65,000	1.15	74,750	.45	29,250
6	.15	3,000	.12	2,400	.10	2,000	.35	7,000
7	.35	91,000	.10	26,000	.15	39,000	.50	130,000
8	.40	64,000	.60	96,000	.30	48,000	.80	128,000
9	1	4,000	.75	3,000	1.50	6,000	3.55	14,200
10	8000	8,000	5000	5,000	10,000	10,000	10,000	10,000
11	.10	25,000	.10	25,000	.10	25,000	.10	25,000
12	3	3,000	6	6,000	2	2,000	3	3,000
13	13.50	405,000	18.80	564,000	18	540,000	21.41	642,300
14	30	90,000	32	96,000	30	90,000	35.54	106,620
15	15	30,000	18.80	37,600	20	40,000	20.16	40,320
16	30	21,000	32	22,400	40	28,000	30.54	21,378
17	12	2,400	18	3,600	10	2,000	9	1,800
18	6	3,600	3	1,800	25	15,000	5	3,000
19	12	8,400	5	3,500	40	28,000	5	3,500
20	1	400	2	800	5	2,000	5	2,000
21	15	630,000	15	630,000	12.75	535,500	12.91	542,220
22	15	112,500	18	135,000	16	120,000	13	97,500
23	.50	2,000	2	8,000	2	8,000	1.99	7,960
24	.50	300	2	1,200	2	1,200	1.99	1,194
25	2	14,000	2	14,000	2	14,000	1.50	10,500
26	20	20,000	25	25,000	6	6,000	12	12,000
27	2.20	187,000	2.50	212,500	1.95	165,750	2.43	206,550
28	3	18,000	2	12,000	1.25	7,500	5	30,000
29	1	2,500	3	7,500	2.50	6,250	1.75	4,375
30	1	2,600	1	2,600	1	2,600	1	2,600
31	2	1,000	4	2,000	2	1,000	3	1,500
32	5000	5,000	6,000	6,000	6000	6,000	8100	8,100
33	1000	1,000	550	550	2,000	2,000	10,000	10,000
Totals		$1,945,100		$2,127,500		$2,188,800		$2,344,177

★ Contract awarded December 28, 1932   Contract executed December 28, 1932

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of 1926, respectfully presents for the year ending November 30, 1934, its

NINTH ANNUAL REPORT

I. Organization and Administration

Davis B. Keniston continued during the year as Chairman of the Commission, and Charles M. Davenport and Thomas D. Lavelle, both of Boston, as Associate Commissioners. R. Nelson Molt continued as Secretary.

The clerical force of the Commission's office at Boston remained substantially the same throughout the year. Three special agents under the direction of the Commission continued to care for the property acquired by the Commission in the Swift River and Ware River areas. Real estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 165 employees during the year. The maximum number employed at any one time by contractors on the various construction projects during the year was 597 persons. In addition, a maximum of 65 persons were employed on force account by the Commission in the clearing operations, in the removal of bodies and in miscellaneous work of maintenance.

The Commission continued, through duly appointed agents, the direction of the town government of the Town of Prescott, as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

II. Engineering Department

Frank E. Winsor continued as Chief Engineer, Karl R. Kennison as Designing Engineer and later as Assistant Chief Engineer, and Walton H. Sears as Mechanical Engineer.

The field divisions were continued in charge of three division engineers as follows: Wachusett-Coldbrook Tunnel Division until November 10 and thereafter the Dam and Aqueduct Division, William W. Peabody; Coldbrook-Swift Tunnel Division, Richard R. Bradbury; Quabbin Reservoir Division, N. LeRoy Hammond.

The Commission retained the services of X. H. Goodnough, Inc., as consulting engineer.

Charles T. Main, of Charles T. Main, Inc., of Boston, was employed from time to time as a general consultant on mill and water power damages and also on the design of the dam and dike of Quabbin Reservoir. Dr. Charles P. Berkey of Columbia University continued as consulting geologist. Other consultants were employed from time to time as needed.

III. Offices

The office of the Commission and of the Chief Engineer continued on the ninth floor of the Metropolitan District Commission Building at 20 Somerset Street, Boston. The division offices for the Coldbrook-Swift Tunnel section of the Quabbin Aqueduct and for the Quabbin Reservoir area continued at Hardwick and Enfield, respectively. The Holden office was discontinued on November 10, after the completion of the Rutland-Holden trunk sewer, which finished the construction work in that district; and the personnel was transferred to the office of the Dam and Aqueduct Division established in Ware just below the Enfield town line at the site of the main dam in buildings previously used as field offices during the construction of the stream control tunnel. The laboratories for water analysis and soil testing were continued at Enfield.

IV. Real Estate and Water Rights

The Commission, for reservoir purposes, has acquired a total of 60,205 acres of land in the Swift River watershed, and for sanitary protection and construction purposes in the Ware River watershed a total of 5,591 acres.

The Board of Referees, appointed under the provisions of Section 5, Chapter 321 of 1927, continued throughout the year with the following personnel: Nathan P. Avery, Esq., of Holyoke, Chairman, Robert W. King, Esq., of Springfield and Joseph Wiggin, Esq., of Malden, the latter being appointed November 30, 1934, to succeed James H. Healy, Esq., of Springfield, resigned.

The Commission has, during the year, concluded settlements with one owner of a water privilege on the Ware River for the diversion of waters of the Ware River and with four owners of water privileges on the Chicopee and Connecticut Rivers for all claims for present and future damages caused by the diversion of the Ware and Swift rivers.

The Commission has reached an agreement with the New York Central Railroad and the Boston & Albany Railroad, Lessees, for the purchase of the railroad property in the area to be submerged and for the abandonment of that part of the Athol Branch which can no longer be operated, subject to the approval of the State Department of Public Utilities and the Interstate Commerce Commission. The agreement included the disposition of the claims of the Western Union Telegraph Company and the removal of its lines.

V. Ware River Supply

James J. Coughlan & Sons, Inc., continued under Contract 39 for the construction of the Rutland-Holden trunk sewer. At the end of the year the contract was practically completed and under the terms of the Commission's agreement with the City of Worcester for the disposal of sewage to be diverted from the watersheds of the Ware and Quinapoxet rivers and the watershed of Wachusett Reservoir into the sewerage system of the city, the city constructed the necessary connecting link within its own limits. The new system was put into operation November 7. Agreements are pending with the United States Veterans Administration and the State Department of Public Health covering the connections of the sewers of their hospitals in Rutland and the use of the Rutland-Holden trunk sewer for the diversion of the sewage to the Worcester sewerage system.

The temporary chlorinating plant located at the point of disposal of sewage from the Rutland Prison Camp was discontinued upon the abandonment of this camp. One other chlorinating plant installed in the upper watershed of the Ware River was maintained in readiness for operation.

No water was diverted during the year from the Ware River.

VI. Swift River Supply

Real estate and topographic surveys were continued during the year.

The Wenzel and Henoch Construction Company continued under Contract 20 for the construction of the Coldbrook-Swift section of the Quabbin Aqueduct. The tunnel lining has been continued and about 98% of the 10.4 miles of the tunnel included in this contract has been lined with concrete.

The West Construction Company continued under Contract 36, for the construction of a core wall to sound rock at the site of the dike of Quabbin Reservoir in the towns of Enfield and Ware. All 31 caissons were sunk and sealed to sound bedrock and the open-cut trench across the valley refilled around and over the caissons with impervious refill. The contract is practically completed.

The New England Power Company and the Central Massachusetts Electric Company completed, on February 15, its relocation of power transmission lines extending across Quabbin Reservoir site

Carlo Bianchi and Company, Inc., V. Barletta Company and John Iafolla Construction Company continued under Contracts 41, 43 and 44, for the construction of the new highway west of the reservoir site about 21 miles long from Belchertown to a point on the road between North Dana and Orange just north of the Orange town line. At the end of the year the highway was practically completed and, except for its central portion built under Contract 43, had been taken over by the Department of Public Works as a state highway, November 20.

Contract 45 was awarded on February 6, to B. Perini & Sons, Inc., Framingham, Mass., for exploration by shovel cuts of borrow areas for the construction of the main dam and dike. The work was completed on October 22.

Contract 50 was awarded on November 26 to The Arthur A. Johnson Corporation, for constructing the embankment of the dike of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware.

VII. Plans for Power Development

The engineering force continued its studies of the development of hydroelectric power at various points on the work. No electric power development is practicable until the completion of Quabbin Reservoir provides the necessary storage of water. As soon as such storage is available there will be two points where such power can be developed. One is at the point where Quabbin Aqueduct tunnel discharges into the upper end of Wachusett Reservoir, the head being due to the fact that Quabbin Reservoir is 135 feet higher than Wachusett Reservoir. The other point is at the main dam where the requirements of Massachusetts legislation, and of the War Department in the interest of navigation in the lower Connecticut River, require certain specified releases and where, after and not until the reservoir is completely filled, occasional surplus flood flows also will be available.

Provisions have been made in the design of all structures to permit the future development of power as soon as Quabbin Reservoir is filled sufficiently to produce the necessary head.

In the building already constructed over the outlet at Shaft 1 where Quabbin Aqueduct discharges into Wachusett Reservoir, space has been provided for the installation of a hydroelectric generating unit. The shaft underneath has been lined with heavy steel plate to take the pressure due to the head used in the power development, and a branch opening from the shaft has been provided with a flange to take the penstock to the water wheel. At Shaft 2, located about two miles westerly from the outlet at Shaft 1, an opening has been left in the shaft lining to provide for the diversion of the Quinapoxet River into Quabbin Aqueduct. Such a diversion would intercept the flow of the river at the head of the gorge through which it now discharges into Wachusett Reservoir and would allow the water to be stored at the higher level in Quabbin Reservoir. This would have advantages not only from the standpoint of water supply but power development as well. In the outlet of the stream control tunnel at the main dam a setting has already been provided in the concrete masonry walls of the discharge channel for a hydroelectric generating unit to generate power from the quantities of water required by law to be released each day from the reservoir at the main dam.

No power can be economically developed at the Ware River intake. There only flood flows, those in excess of 85 million gallons daily, are available. Any development of electric power at this point would, therefore, be limited to periods when there is high water, and even in such periods the quantities available are intermittent and vary within very wide limits. Upon the completion of Quabbin Reservoir, however, the draft for water supply will be controlled by gates at the east or the Wachusett end of Quabbin Aqueduct tunnel so that the tunnel will become in effect a part of Quabbin Reservoir. The water from the Ware River diverted into the tunnel can then be stored as required in Quabbin Reservoir and can be used to generate power at the point of discharge into Wachusett Reservoir.

VIII. Cemeteries

The Commission has continued the assignment of lots in the new Quabbin Park Cemetery and 493 bodies were removed from the Quabbin Reservoir area during the year of which 475 have been interred in Quabbin Park Cemetery. To date a total of 1,912 bodies have been removed from the Quabbin Reservoir area; and there have been 54 original burials in this cemetery.

IX. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

X. Other Reports

The report of the Chief Engineer is herewith presented.

Respectfully submitted,
DAVIS B. KENISTON, *Chairman.*
CHARLES M. DAVENPORT, *Associate Comissioner.*
THOMAS D. LAVELLE, *Associate Commissioner.*

20 Somerset Street, Boston, Mass.
December 27, 1934.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN:—The following is a report of the engineering department for the year ending November 30, 1934.

ORGANIZATION

In numbers the engineering organization has been decreased about 4% during the year.

Karl R. Kennison, Designing Engineer until September 26 and since then Assistant Chief Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, preparation of contract specifications, contract and working drawings.

Charles L. Coburn and Stanley M. Dore, Assistant Designing Engineers, continued their general supervision of the detailed work of the office; and Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. They have assisted in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Wachusett-Coldbrook Tunnel Division until its discontinuance November 10, and thereafter in charge of the Dam and Aqueduct Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division; N. LeRoy Hammond, Quabbin Reservoir Division.

X. Henry Goodnough, Inc., continued as consulting engineer. Charles T. Main, consulting engineer of Boston, Dr. Charles P. Berkey, geologist of Columbia University, Arthur A. Shurcliff, landscape architect of Boston, and other experts were employed from time to time.

The assignment of employees under the direction of the Chief Engineer at the end of the year and of the preceding year was as follows:

	Nov. 30, 1933	Nov. 30, 1934
Headquarters Office, Designing Division	38	39
Holden Office, Wachusett-Coldbrook Tunnel Division	26	—
West Ware Office, Dam and Aqueduct Division	—	19
Hardwick Office, Coldbrook-Swift Tunnel Division	40	40
Enfield Office, Quabbin Reservoir Division	61	61
Total Engineering Force	165	159

The maximum force during the year was 167, during the five weeks ending August 4, and three weeks ending September 8. The minimum force was 159, during the five weeks ending November 30. The average force for the year was 165.

OFFICES

The office of the Chief Engineer and Designing Division was continued in the Metropolitan District Commission Building at 20 Somerset Street, Boston. The field office of the Wachusett-Coldbrook Tunnel Division was continued at Washburn Hall, Holden Center, until the practical completion of all construction work in this division November 10. Thereupon a field office for the Dam and Aqueduct Division was established in West Ware at the site of the main dam of Quabbin Reservoir in buildings formerly used as field offices during construction of the stream control tunnel. The field office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center. The field office of the Quabbin Reservoir Division was continued in the property of the Commonwealth formerly known as the Frances W. Chandler house on Quabbin Road, and the laboratories for water analysis and for soil testing were continued in the property of the Commonwealth formerly known as the Barlow house, in Enfield.

HEADQUARTERS OFFICE

Summary of the Year's Work

Real Estate. — Reports and recommendations with respect to the purchase of real estate in the Quabbin Reservoir area were submitted to the Commission during the year covering 4,223 acres, making a total reported on to date of 75,233 acres.

Progress of Real Estate Purchases for Quabbin Reservoir

	Total Area Negotiated Including Owners' Offers to Sell to Commonwealth (Acres)	Area not Required (Acres)	Title Vested in Commonwealth (Acres)
Total for Year ending Nov. 30, 1934	4,223	269	4,893*
Total to Nov. 30, 1933	71,010	7,195	54,307
Total to Nov. 30, 1934	75,233	7,464	59,200

Options outstanding Nov. 30, 1934, include 1,005 acres.
*Includes some offered in previous years.

Reports and recommendations were also made with respect to the purchase of real estate for sanitary protection in the Ware River watershed above the intake works at Coldbrook.

Progress of Real Estate Purchases for Ware River Watershed Protection

	Title Vested in Commonwealth (Acres)
Total for year ending Nov. 30, 1934	273
Total to Nov. 30, 1933	5,259
Total to Nov. 30, 1934	5,532

Options outstanding Nov. 30, 1934, include 59 acres.

Real estate taking plans were prepared and filed during the year as shown in the appended table.

Diversion, Land, and Business Damage Cases

Data were prepared for the use of the attorneys in water diversion, land and business damage cases before the courts and before the Board of Referees. Conferences were held and data collected jointly with representatives of manufacturers that have filed claims for diversion damages.

Contracts and Specifications. — Plans and specifications were prepared for Contract 45, for exploration by shovel cuts of borrow areas for the main dam and dike of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware. The contract was executed February 7.

Contract 46 was prepared, being an agreement with the United States Veterans Administration as to compensation for the right to discharge the sewage of the Administration's hospital in Rutland into the Rutland-Holden sewer, constructed under Contract 39. The agreement was completed August 30 and became effective when the sewer connection was completed on November 7.

Plans and specifications were prepared for Contract 50, for constructing the embankment of the dike of Quabbin Reservoir in the towns of Enfield and Ware. Bids were received November 13; the contract had not been executed at the end of the year.

Working drawings for Contracts 20, 36, 39 and 44 were prepared and issued.

Work was in progress on the preparation of an agreement with the State Department of Public Health as to compensation for the right to discharge the sewage of the Rutland State Sanitorium into the Rutland-Holden sewer, constructed under Contract 39.

Work was continued on the preparation of plans and specifications for constructing a core wall to sound rock at the site of the main dam of Quabbin Reservoir in the towns of Enfield, Belchertown and Ware similar to that being constructed under Contract 36 at the site of the dike.

Work was in progress on the preparation of plans and specifications for constructing a head house at Shaft 9 of the Quabbin Aqueduct tunnel.

Inspection and Tests. — E. L. Conwell and Company continued the testing of cement. The Worcester Polytechnic Laboratory continued the testing of concrete cylinders, and steel reinforcement bars were tested there and at the laboratory of the Massachusetts Institute of Technology. William R. Conard of Burlington, N. J., continued the inspection of cast-iron pipe furnished for the Rutland-Holden sewer under Contract 39. The inspection of iron castings furnished under Contract 20 was made by the engineering force.

Hydrographic Data. — The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey.

The gaging station on the Chicopee River at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and the United States Geological Survey.

The gaging station on the Chicopee River at the Red Bridge plant of the Ludlow Manufacturing Associates was continued in cooperation with that company.

The gaging station on the Swift River at Bondsville was continued in cooperation with the Otis Company.

A recording station was established on the Swift River above the intake to the stream control tunnel at the main dam site and measurements were made to establish the rating curve.

Cooperation with the United States Geological Survey in the operation and maintenance of the gaging station on the Connecticut River at Thompsonville, Connecticut, was continued.

In connection with the examination of the waters of the Ware, Swift and Chicopee rivers, observations of flow were continued from time to time and additional temporary gaging stations established as required and data for the use of consultants and experts were prepared.

Ware River Diversion

There was no diversion of Ware River water into Wachusett Reservoir. In the period June 15 to October 15, inclusive, in conformity with the requirements of the War Department, no water was diverted. At other times, the daily flow in the river was frequently sufficient to permit diversion, but no diversion was made because of the present inadequacy of storage capacity in the reservoirs of the District.

Sewage Diversion from Ware River Watershed

The Rutland-Holden Sewer was put in operation November 7. From November 7 to 30, inclusive, 1,709,000 gallons of sewage were received from the U. S. Veterans Hospital and 2,953,500 gallons discharged into the sewerage system of the City of Worcester.

Design of Structures

Shaft 9. — Designs were continued for a head house at the top of Shaft 9 and an access road from the main highway.

Shaft 11A. — Designs were made for an outlet shaft 5,646 feet west of Shaft 11 at a point where the tunnel passes beneath the future shore line of Quabbin Reservoir. Flood flows from the Ware River can be discharged through this outlet shaft into a small arm of the future reservoir south of Pottapaug Pond on the east branch of the Swift River. Provisions will be made for one-way shutters or so-called tide gates at both Shafts 11A and 12. Those at Shaft 11A will allow the water from the Ware to be discharged from the tunnel near the surface of the reservoir and prevent a flow in the reverse direction from the reservoir into the tunnel at this point. Those at Shaft 12 will allow the draft from the reservoir to enter the tunnel and also prevent the water from the Ware from being discharged into the reservoir at this point. These devices were designed to secure the benefit of longtime storage for all the water drawn from Quabbin Reservoir to Wachusett Reservoir through the aqueduct, and to discharge the, at times, highly colored water diverted from the Ware River, into the reservoir at a point remote from the intake at Shaft 12. The distance between these two shafts, measured along the shortest line of travel through the reservoir, is about three miles. The design of Shaft 11A includes provision for the venting of air, as in the case of all other shafts.

East Branch Baffle. — Studies were made which indicate the desirability of building a baffle across the East Branch of the Swift River near the outlet of Walker Mill Pond which would divert the entire flow of the East Branch northerly along the east side of a large island to enter the main body of the reservoir about 4 miles northerly from the intake at Shaft 12. By the construction of such a baffle the water from the East Branch, which is the largest feeder of the reservoir, and from the Ware would obtain the very important benefit of longer storage, the former having a travel through the reservoir of 13 miles and the latter of 11 miles, the increased travel being 8 miles in each case.

Shaft 12. Swift River Intake. — Studies were continued of the requirements of a head house and a service building and of grading at the intake. Studies were made of one-way shutters designed to permit the drawing of water into the tunnel from any desired level and to prevent discharge into the reservoir of water diverted

from the Ware. Studies were made of a channel to be excavated to the low level intake from the present Quabbin Lake on the east branch of the Swift River.

Pumping Ground Water. — Studies were continued of the permeability of foundation materials at both the dike site and the main dam site, particularly the latter. Designs were made for two additional exploratory caissons on the line of the proposed caisson core wall at the main dam. These designs included pumping plants in the working chambers of these caissons which were sunk and sealed to ledge under Contract 36; weir boxes for the collection and measurement of this pumpage and also that from the preliminary exploratory caisson sunk under Contract 32; and a 24-inch steel pipe line from the weir boxes, a distance of about 1,000 feet, to the river at a point above the intake to the approach channel of the stream control tunnel.

The old river bed was made dry for the entire distance of 2,300 feet between cofferdams commencing December 21, 1933. The pumpage of about 2,200 gallons per minute from the first exploratory caisson, numbered 20, was supplemented by pumpage from the working chambers of the two additional exploratory caissons numbered 7 and 9 from time to time during their sinking. On October 21, the pumping station was completed at the bottom of one of the additional caissons, numbered 9, and pumpage from this caisson was commenced at the rate of 1,200 gallons per minute. On November 28, the pumping station at the bottom of the third caisson, numbered 7, was completed and pumpage commenced from this caisson at the rate of 3,000 gallons per minute. These two additional exploratory caissons were put down at practically the deepest point in the rock gorge, and upon their completion the rate of pumpage from caisson 20 had been reduced to 800 gallons per minute, making a total pumpage of ground water at the main dam site at the rate of 5,000 gallons per minute which continued until the end of the year. During the sinking of these additional exploratory caissons, the ground water level was lowered from 15 feet below the water level in the river to about 35 feet below the river level. After the completion of the two additional pumping plants, the ground water level has been further reduced in 20 days to about 65 feet below the river level.

At the dike site pumping was continued from the caissons sunk under Contract 36 until November 21.

The work now accomplished at the main dam indicates clearly the feasibility and economy of lowering the ground water level during the sinking of the caisson cut-off wall, hereinafter described. The investigations indicate that the permeability of the glacial overburden at the main dam site exceeds that at the dike site by about 50%.

Caisson Core Wall at Main Dam. — Designs were continued for a concrete core wall from the original surface to sound rock in the bottom of the valley at the site of the main dam to be constructed by sinking from the bottom of an open-cut trench a row of caissons, each 9 feet thick and 45 feet long, in the same manner as was successfully done under Contract 36 at the site of the dike. The design calls for 40 caissons including exploratory caissons 7 and 9 sunk during the year under Contract 36 and caisson 20 previously sunk under Contract 32, or a total of 9 more than at the dike, where 31 have been sunk. Studies were continued of the economical depth of open-cut trench to be first excavated before starting the sinking of caissons and the bottom of the trench in the deepest portion of the valley was fixed at about 20 feet below the river bottom or about 30 feet below the general level of the original surface, the remaining distance to ledge being about 90 feet.

Soil Fills. — Studies were made of methods of determining the degree of compacting of rolled soil fills, and a soil penetration needle was designed for field tests of the impervious refill of the open-cut trench around the top of the caisson core wall under Contract 36, and used in connection with laboratory tests of the per cent of moisture in the material.

Shallow Flowage. — Studies were made of the possibility of eliminating certain areas of fluctuating shallow flowage in the margins of Quabbin Reservoir by the construction of low dams to maintain the water level.

Studies were also made of the expected general trend of currents in Quabbin Reservoir and the quality of the water after storage.

Boat House. — Studies were made of locations for a boat house and marine

railway to take care of future reservoir inspection service under the condition of fluctuating reservoir level.

Main Dam Spillway. — Studies were continued to determine the best location for the main spillway of Quabbin Reservoir, and a location was adopted for an overflow spillway with a crest 400 feet long built on solid ledge in a natural depression between two projecting hilltops east of the dam site. Designs were made of a channel from this spillway to the river level 150 feet below, the entire drop being in solid ledge.

Power Development at Main Dam. — Studies were continued of the development of hydroelectric power at the outlet works downstream from the stream control tunnel at the main dam. At the outlet of the stream control tunnel a setting has already been provided in the concrete masonry walls of the discharge channel for a hydroelectric generating unit to generate power from the water required to be released from the reservoir.

Tunnel Inspection. — Studies were made of floating equipment to use in inspecting the Quabbin Aqueduct tunnel and of hoists for handling the same at Shafts 4, 9 and 12.

Main Dam and Dike. — Studies were continued and designs made for the embankments of the main dam and dike.

Studies were continued of methods of utilizing existing materials in the construction of embankments, resulting in the adoption of the full-hydraulic method of constructing the dike. For the benefit of prospective bidders for the construction of the dike embankment, plans were made of layouts for the contractor's plant: (1) in the case of direct sluicing, mainly from borrow areas northeast of the dike site: (2) in the case of sluicing from mixing boxes fed by truck haul from borrow areas on the west side of the valley: and (3) in the case of sluicing from hog boxes supplied mainly by railroad haul from borrow areas northwest of the dike site.

Photographic Records. — The taking of moving pictures from time to time to illustrate the progress of construction was continued.

Office Buildings. — Studies were made of the locations and requirements of permanent office and maintenance buildings that will be required after the completion of the work.

Roads. — Studies were continued of highway relocation at Quabbin Reservoir and designs were made for access roads to the main dam and to the dike.

Railroad. — Further studies were made of the discontinuance of that portion of the Athol Branch of the Boston and Albany Railroad which will be affected by the construction of the Quabbin Reservoir.

Ware River Intake Works. — Designs were made for a reinforced concrete bulkhead and orifice at the entrance to the 52-inch Venturi meter in the Ware River intake works to replace an experimental timber bulkhead used to regulate the water level in the approach to this meter.

Quinapoxet River Diversion. — Studies were continued of the desirability of diverting into the aqueduct at Shaft 2 the waters of the Quinapoxet River for storage in Quabbin Reservoir, provision for which was made in the construction of the shaft. Such diversion has various advantages both from the standpoint of water supply and power development.

Wachusett-Coldbrook Tunnel Division — Holden Office
Dam and Aqueduct Division — West Ware Office

The Wachusett-Coldbrook Tunnel Division until November 10, and thereafter the Dam and Aqueduct Division with the same personnel and with its office at the main dam in West Ware, continued in charge of all work in connection with improvements on the Ware River watershed, of the location and construction of the Rutland-Holden sewer, of the maintenance and operation of the Ware River intake works at Coldbrook and the Wachusett outlet works at West Boylston, of a portion of the surveys for highway relocation in the Quabbin Reservoir area, and of field studies of materials and methods of construction of the main dam and dike.

Office Work

Semi-monthly estimates were prepared for Contract 39 and the final estimate was well advanced. Monthly estimates and the final estimate were prepared for

Contract 39. — Rutland-Holden Sewer, Construction in Sheeted Trench.

Contract 41. — Looking North at Pelham Center along the New Highway West of Quabbin Reservoir.

Contract 45. Additional real estate plans were prepared of miscellaneous property in the Ware River watershed, final tracings being made of about 1,765 acres. Record plans were made of the area along the tunnel line and along the watershed divide. Topographic maps were made of the area along the Quinapoxet River in the vicinity of Shaft 2. Daily rainfall and temperature records and continuous records of the flow of the Ware River were kept at the intake building, and daily rainfall records were kept at West Rutland. The division continued its cooperation with the Enfield office in the studies and preparation of plans for the relocation of highways at Quabbin Reservoir. Studies were continued of materials, comparative costs and methods of construction of the proposed main dam and dike.

Field Work

Topographic surveys were made in the Quinapoxet River valley near Shaft 2 covering about 110 acres, and along the line of the Ware River watershed divide. At the end of the year about 98% of the divide above the point of diversion had been surveyed. Lines and grades were given for construction of Contracts 39 and 45. Additional stone bounds were set during the year completely defining the limits of property and easements acquired by the Commission along the line of the tunnel. The triangulation system in the Ware River drainage area was extended and tied to other systems of the United States Coast and Geodetic Survey and of the State Commission on Waterways and Public Lands.

Monthly inspections and reports were made of conditions found at all shaft heads along the Wachusett-Coldbrook Tunnel section of Quabbin Aqueduct.

The State Department of Public Health continued its cooperation with this division in the analysis of samples of water and sewage effluents. The use of the Rutland Prison Camp and Hospital on the Ware River watershed was discontinued on November 30, 1934, and the chlorinator station for the sewage effluent from the camp discontinued. The chlorinator station on Mill Brook below the Rutland State Sanatorium and the Central New England Sanatorium was maintained but due to the fact that no water was diverted at the Ware River intake works it was not operated.

In connection with studies of the method of construction of the proposed main dam and dike, surveys of top soil and of glacial overburden were made in the vicinity of both structures.

Operation of Ware River Intake Works

Operation of the Ware River intake works was continued. No water was diverted into the tunnel during the year. The tunnel was entered for inspection through Shaft 8 on December 22, 1933. The steel bulkhead 2,200 feet west of Shaft 8 continues in excellent condition. The concrete tunnel lining east of the bulkhead and adjacent to the construction operations under Contract 20 was found to be clean and in excellent condition.

Miscellaneous Construction

On September 7, the pond back of the diversion dam was drawn down and the temporary timber bulkhead, which since the commencement of operation of the works has served to control the water level at the entrance of the 52-inch Venturi meter, was replaced with reinforced concrete construction. When the meter was unwatered for these operations the interior was examined and found in excellent condition. A small labor force was employed on this installation.

A small labor force was employed throughout the year on miscellaneous work in caring for the grounds at the Ware River intake, Wachusett outlet and Shaft 4 head house, setting stone bounds, filling cellar holes, grading and cleaning up at the sites of buildings removed from the Ware River watershed and other miscellaneous work. The average number of men employed on force account was 4 and the maximum 6.

Progress of Contracts

Contract 39. Contract 39, for constructing the Rutland-Holden sewer in the towns of Rutland and Holden, continued in force throughout the year. This sewer consisting of 10-inch, 12-inch and 16-inch cast-iron pipe extends 9.17 miles from near the Rutland State Sanatorium in Rutland with a 0.33 mile branch from

the United States Veterans Hospital, to a connection with the Worcester sewerage system.

Excavation of the trench was generally made by two 1-cubic yard back diggers, and a ½-cubic yard crane where ledge was encountered. The excavation was completed the latter part of October with practically no sheeting or bracing except in a length of about 1,430 feet at the easterly end where sheeting was generally used and single or double sheeting was ordered left in place for a distance of 232 feet and about 360 feet of underdrain was installed. The work was carried on substantially as described in the report for the previous year.

The Worcester Brook, Asnebumskit Brook and Eagle Lake embankments which were practically completed at the beginning of the year were completed and dressed with soil. Embankments at Dawson, Newell Road and south of Newell Road were continued to completion. All the embankments were seeded except for small areas totaling about ⅛ of an acre, where because of the lateness of the season, seeding was omitted from the Contract and will be done next spring.

A total length of 50,865 feet of pipe was laid. The average rate of pipe laying was about 827 feet per week, the maximum in any one week being 2,340 feet.

Five pipe culverts were constructed. One hundred and ten manholes were constructed, making a total of 129.

Measuring station A at the State Sanatorium was completed August 29; measuring station B at the United States Veterans Hospital, May 10; and measuring station C at the Worcester County Line, July 9. At the end of the year the work was practically completed. On November 7, the physical connections with the existing sewers of the Rutland State Sanatorium and the United States Veterans Hospital were completed and the sewer was put in operation.

The value of work included in contract estimates during the year was $157,899.71, or a total to November 15, the date of the latest estimate, of $213,915.46, of which 90% was approved for payment. The contractor's force averaged 45 men, the maximum being 67 for the week ending September 15.

The total work done and materials furnished to date under the principal items of Contract 39 are as follows:

Excavating and refilling trench	46,183 lin. ft.
Earth excavation, except in trench	12,761 cu. yds.
Rock excavation	6,571 " "
Furnishing and laying 10-inch pipe	7,186 lin. ft.
Furnishing and laying 12-inch pipe	20,722 " "
Furnishing and laying 16-inch pipe	22,957 " "
Foundation embankment	39,905 cu. yds.
Concrete in manholes	569 " "
Concrete, except in manholes	510 " "

Contract 45. — Bids were opened February 6 for exploration by shovel cuts of potential borrow areas for the main dam and dike of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware. Six bids were received, ranging from $6,200 to $12,400. The contract was executed February 7, with B. Perini & Sons, Inc., Framingham, the low bidder.

Excavations were made at eight locations, four each in borrow areas considered for the construction of the main dam and for the dike. The work was started March 6 and completed October 19, involving a total of 23,233 cubic yards. A one-cubic-yard shovel was used and material was handled by trucks.

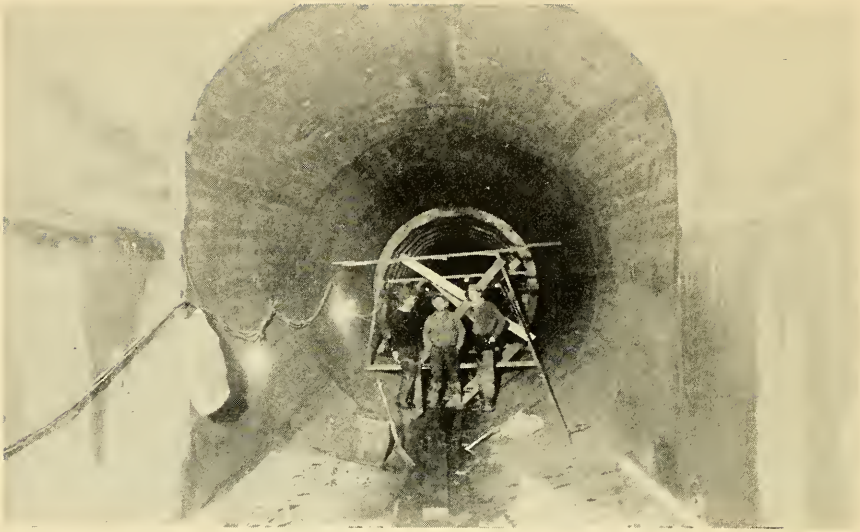
The amount of the final estimate dated October 22, 1934, was $9,425.09, of which $9,090.00 has been paid. The contractor's force averaged four men with a maximum of seven during the week ending March 17.

Coldbrook-Swift Tunnel Division — Hardwick Office

The Coldbrook-Swift Tunnel Division continued in charge of the construction of the Coldbrook-Swift Tunnel section of Quabbin Aqueduct and of river surveys along the Ware, Swift and Chicopee rivers.

Office Work

Tunnel cross sections were plotted and excavation and masonry volumes computed therefrom. Semi-monthly estimates were prepared for Contract 20. Topographic maps were made for an access road to Shaft 9, at and near Shaft 11A and for a portion of the Quabbin Reservoir Watershed divide. Plans and topographic maps were made of various ponds on the Ware and Swift rivers and tributaries.



Contract 20. — Quabbin Aqueduct Tunnel, Lining of Transition to Circular Pressure Section East of Shaft 12.

Contract 36. — Dike Core Wall, Underpinning to Bedrock at the Bottom of Caisson Number 5.

The preparation of geologic field notes and specimens for a permanent geologic record was continued.

Field Work

Lines and grades were given for construction on Contract 20. About 195 acres of topography were taken along the Ware River and tributaries below the intake, about 700 acres along the Swift River below the proposed main dam, about 45 acres along the Chicopee River and about 80 acres in the vicinity of Shafts 9 and 11A. Soundings were taken in about 500 acres of ponds along these rivers and about 175 acres of ponds on the watershed above the intake. The watershed divide of Quabbin Reservoir was located for a distance of about 12 miles. The State Department of Public Health continued its cooperation in the analysis of samples of drinking water used in the different contractors' camps. Photographs of the construction work and of rock formations of geological interest were continued. Geological investigations in connection with the tunnel construction were continued to completion. The division also continued its cooperation with the Enfield office in geological investigations in connection with the dike caisson core wall, and exploratory caissons at the main dam, under Contract 36. Special castings for Contract 20 were inspected at the foundry.

Collection of Stream Flow, Water Power and Other Data Pertinent to Mill and Water Power Damages

The collection of data pertinent to the determination of the water power available and developed at various plants on the Ware, Swift and Chicopee rivers and to the determination of flows at various points under varying conditions was continued. Recording stream gaging stations were continued at White Valley and Ware on the Ware River and at Bircham Bend on the Chicopee River. A recording station was established on the Swift River above the intake to the stream control tunnel and measurements were made to establish the rating curve.

Miscellaneous hydraulic measurements were made on the watersheds of the Ware, Swift and Chicopee rivers including observations of water levels under flood conditions and determinations of the capacities of various ponds.

Investigation of the quality of the water in the Ware, Swift and Chicopee rivers and tests to determine the quality and quantity of industrial wastes discharged into the Ware and Swift rivers were made in cooperation with the laboratory at Enfield, the collection of hydraulic data and in general the collection of samples for analysis being carried on by this office.

Progress of Contracts

Contract 20. — Contract 20, for the construction of the Coldbrook-Swift Tunnel section of Quabbin Aqueduct, through the towns of Barre, Hardwick and Greenwich, continued in force throughout the year. This tunnel extends 10.4 miles from the end of the completed Wachusett-Coldbrook section to the Swift River intake in the town of Greenwich.

At the end of the year about 96% of the value of the work was completed. This included all tunnel excavation and the lining with concrete of about 53,774 feet of tunnel, a length of about 28,774 feet being lined during the year. A length of about 1,088 feet of tunnel remains to be lined under this contract. The concrete mixing plant at the lower intake just outside of the tunnel portal west of Shaft 12 was completed, and a mixing plant was also set up and operated at the top of Shaft 10. The selection, crushing and screening of tunnel spoil for use as concrete aggregates were continued at all shafts. The screening plant at Shaft 10 was destroyed by fire on July 23 but was rebuilt sufficiently to complete the lining at that point. The screening and crushing plant at Shaft 11 was destroyed by fire January 2. Concreting was continued with the aggregates on hand until January 26 when a temporary screening plant was erected and used until the end of the concreting at this shaft. The tunnel plants for placing of sidewalls, arch and invert were moved to Shafts 10 and 12 when the lining at Shafts 9 and 11 was completed.

The aggregate plants built during the year were of the dry-screening type instead of the washing plants previously used. The arrangement of dragline and grizzly

was unchanged. From the grizzly a short conveyor belt carried the material to two rotary screens where it was heated by blasts from oil-burning jets. The fine material from the first part of the screen passed a blower as it fell and the finest particles were blown into a large waste pipe, mingled with a stream of water and carried to settling basins. The coarser sand was carried by a conveyor belt to the sand storage pile. Material from the remainder of the screen was carried by another conveyor belt up an incline, dropped on an inclined screen and washed by jets of water to remove all fine particles. The stone was then dropped to the stone aggregate pile and the fines carried off and wasted. Stones too large to pass this screen were chuted to two supplementary crushers and returned to the circuit. The different units were separately motor driven.

Cement was received in bulk shipments except that a small quantity of bag cement was used for completing the invert at the bottom of Shaft 9, for lining Shaft 12 and for grouting. The aggregates were batched and the concrete mixed and dropped down the shaft and placed in the same manner as described in the report for the previous year, except that two 2-yard mixers were used at Shaft 10 and concrete for the invert was delivered directly in cars hauled up the ramp and through the arch forms. The average weekly progress in placing concrete lining from seven tunnel plants for all of the tunnel lining to date was 371 feet per plant. The maximum in one heading was 705 feet in the week ending March 24 from the lower intake. The contractor continued to employ local physicians who made weekly reports on the health of his employees and on the sanitary conditions of each of his camps and to employ a safety engineer for the improvement of working conditions in the tunnel.

The value of work included in contract estimates during the year was $562,-855.06, or a total to November 22, the date of the latest estimate, of $4,604,513.39, of which $4,444,062.05 was approved for payment.

Shaft 9. — At the beginning of the year the contractor had completed the lining from this shaft, except a length of 41 feet at the bottom of the shaft which remains unlined, and except 463 feet of invert which was placed during the latter part of August. The tunnel lining plant in the west heading was removed and the plant in the east heading was moved through the tunnel for use in the east heading of Shaft 10. Commencing July 28 work of drilling vent and grout holes was started. All necessary grouting was done from September 1 to October 25. The tunnel was then cleaned. The completion of the lining at the bottom of the shaft and the grouting of the shaft are now in progress. The contractor's force averaged eight men, the maximum being 24 during the week ending December 23, 1933. The contractor's camp at this plant was unoccupied except by a watchman.

The only additional plant items required were one grouting machine and one guniting machine.

Shaft 10. — No work was done at this shaft until February 3 when the contractor started to remove the crushing plant and install concreting plant. Tunnel lining plant including 125 feet of forms was moved from the west heading of Shaft 11 on April 29, and tunnel lining plant with 125 feet of forms from the east heading of Shaft 9 on May 7. Concrete lining was started in the east heading on June 21 and in the west heading on July 5. The screening plant at the top of Shaft 10 was destroyed by fire on July 23. Repairs were completed and concrete lining continued in the west heading on August 6 and in the east heading on August 9. At the end of the year the lining had been carried to within 521 feet of the shaft easterly and 499 feet westerly. The average weekly progress of the tunnel lining was 432 feet in the east heading and 423 feet in the west heading, the maximum being 498 feet in the east heading and 625 feet in the west heading in the week ending September 1. The contractor's force averaged 58 men, the maximum being 130 during the week ending October 13. The average number of persons occupying the camp was 11, the maximum population being 28 during the week ending July 21.

There was no material change in plant items during the year.

Shaft 11. — The tunnel lining was continued, progress being rather slow during the winter on account of weather conditions at the surface plant. The crushing and screening plant at the top of the shaft was destroyed by fire on January 2. Lining was continued using available stored aggregates until January 26 when a temporary screening plant was erected and used until the concreting was stopped

on March 13, the lining being completed except for a length of 27 feet at the bottom of the shaft. The tunnel lining plant in the east heading was dismantled and removed and that in the west heading was taken through the tunnel to the west heading of Shaft 10. Beams and slabs for the cover at the top of the shaft were precast August 25. Grouting operations in the tunnel were started on November 7 at the timbered section east of Shaft 12. The average weekly progress of the tunnel lining was 212 feet in the east heading and 220 feet in the west heading, the maximum being 375 feet in the east heading and 526 feet in the west heading, in the week ending December 9, 1933. The contractor's force averaged 21 men, the maximum being 113 during the week ending December 9, 1933. The average number of persons occupying the camp was 5, the maximum population being 20 during the week ending December 2, 1933.

There was no material change in plant items during the year.

Shaft 11A. — Work was started October 1 on grading the access road and clearing the site for this shaft, the design of which is hereinbefore described. The electric transmission line which follows the line of the tunnel was relocated around the shaft October 17, and transformers installed November 2. Earth excavation was started November 6 at the top of the shaft and for the outlet channel, using both a clamshell and dragline bucket. To eliminate the necessity of pumping during the excavation and shaft sinking, the contractor plans to drill a pilot hole about 65 feet through the ledge to the roof of the tunnel and equipment for this purpose is being moved to the site. The contractor's force averaged 4 men.

The principal items of plant were as follows:

One gasoline driven shovel
Clamshell and dragline bucket hoists
One well drilling outfit

Tunnel Vent. — At the beginning of the year the 8-inch hole had been drilled from the bottom of a test pit at the surface for the tunnel vent, the design of which was described in last year's report. The work was continued to completion. The 8-inch hole was lined with 6-inch copper tubing, smooth inside, with butt joints formed by an outside coupling soldered in place as the tubing was lowered. The bottom was then caulked in the tunnel arch and the tubing grouted into the hole. The vent cap was installed about 7 feet above the ground and about 160 feet above the tunnel arch and the grading completed the latter part of July.

Shaft 12 and Swift River Intake. — The contractor continued the installation of the crushing, screening, washing and mixing plant above the cut and cover section of the lower intake just west of the tunnel portal. This plant was completed December 16 and concrete lining commenced December 18. The concrete was conveyed to cars in the tunnel through a 10-inch square chute which passed through an opening left for the purpose in the arch of the cut and cover section just west of the face of the portal cut and later blocked and sealed. The aggregate bins were equipped with steam coils and the mixer house and trap tunnel were steam heated. Concrete was mixed and placed on days when the temperature registered 20° to 25° below zero F., using water heated to 120° F. The tunnel plant at this shaft was similar to that used at other shafts except that only 100 feet of form were used, and the concrete gun was increased in capacity with its hopper equipped with a feed screw. The lining of the regular horseshoe section was completed and the transition made to the circular section east of the shaft on May 12. A circular section of the pressure type was cast for a length of 200 feet just east of the shaft, using wooden forms in 25-foot sections set up on precast concrete pedestals. The tunnel lining was completed May 27.

The average weekly progress of the tunnel lining was 470 feet, the maximum being 705 feet during the week ending March 23. Preparations for lining the shaft were begun early in July. Before the aggregate plant was dismantled enough coarse aggregate was prepared to complete the shaft lining. The supply of sand, however, was inadequate and about 500 cubic yards were borrowed. A one-yard mixer was installed just south of the shaft head and a cement shed built close by. Concrete lining of the shaft commenced July 28 and at the end of the year had reached Elev. 492, about 65 feet above the tunnel arch, 14 feet below the original surface and 47 feet below the foundation floor of the future superstructure.

Work was in progress on dismantling plant and buildings and cleaning up, particularly along the lower intake channel where some additional riprap was placed on the channel side slopes and the berms. Permanent rack bars were placed in the openings of the lower intake channel and the permanent concrete sill completed at Elev. 428, 102 feet below the flow line of Quabbin Reservoir. Rock excavation in the upper intake channel was completed from the shaft to a point about 50 feet west before any concrete forms were placed in the shaft. The construction of a winter housing covering the entire working space at the top of the shaft to allow laying of stone masonry to continue throughout the cold weather is in progress, and a steam boiler for heat and hot water has been installed. The contractor's force averaged 44 men, the maximum being 80 during the weeks ending January 20 and March 24. The average number of persons occupying the camp was 7, the maximum population being 24 during the week ending January 6.

Various changes were made in plant items during the year as above described. At the end of the year there remained

1 Derrick with 40 ft. boom
1 Air compressor, 550 cu. ft. per min. capacity, driven by 125 H.P. motor
1 1-yd. concrete mixer
1 Steam boiler
Carpenter shop equipment
Miscellaneous rolling stock and portable equipment
4 Pumps, the largest having a capacity of 700 gals. per min., under a 100-ft. head and driven by 30 H.P. motor.

Tunnel lining has progressed to date as follows:

	To Nov. 30, 1933	Year ending Nov. 30, 1934	Total Completed	Remaining to be Lined
Shaft 9				
East	7,419 ft.	0 ft.	7,419 ft.	26 ft.
West	6,193 ft.	0 ft.	6,193 ft.	15 ft.
Shaft 10				
East	0 ft.	7,772 ft.	7,772 ft.	521 ft.
West	0 ft.	8,041 ft.	8,041 ft.	499 ft.
Shaft 11				
East	4,679 ft.	2,605 ft.	7,284 ft.	16 ft.
West	6,703 ft.	1,238 ft.	7,941 ft.	11 ft.
Shaft 12				
East	0 ft.	8,805 ft.	8,805 ft.	0 ft.
West	0 ft.	319 ft.	319 ft.	0 ft.
Totals	24,994 ft.	28,780 ft.	53,774 ft.	1,088 ft.
Total length of lining under Contract 20.				54,862 ft.

The total work done and materials furnished to date under the principal items of Contract 20 are as follows:

	Shaft 9	Shaft 10	Shaft 11	Shaft 11A	Shaft 12 and Intake
Earth excavation for shafts (cu. yds.)	84	318	225	—	*
Rock excavation in shafts and in tunnel within 50 feet of shafts (cu. yds.)	2,335	3,617	2,660	—	1,445
Excavation in tunnel, except within 50 ft. of shafts (cu. yds.)	101,791	104,212	106,993	—	60,582
Shaft and tunnel drainage (lin. ft.)	11,397	11,632	11,726	—	6,791
Earth excavation in open cut (cu. yds.)	—	2,500	1,803	1,570	38,229
Rock excavation in open cut (cu. yds.)	—	435	106	20	2,381
Forms for concrete lining in shafts (lin. ft.)	178	397	258	—	—
Forms for concrete lining in tunnel (lin. ft.)	13,612	15,314	15,225	—	9,090
Concrete masonry in shafts (cu. yds.)	420	929	611	—	—
Concrete masonry in tunnel (cu. yds.)	28,542	32,736	31,933	—	18,979
Concrete masonry not in shafts or tunnel (cu. yds.)	—	—	1	—	1,896
Permanent timbering in tunnel (M ft. B.M.)	34	215	54	—	26
Temporary timbering in tunnel (M ft. B.M.)	10	—	4.5	—	—
Portland Cement (bbls.)	48,616	53,195	51,375	—	31,239
Gunite protective coating of tunnel rock (lin. ft.)	3,994	3,453	—	—	—
Refilling and embanking (cu. yds.)	—	1,625	—	500	5,253
Miscellaneous cast iron, wrought iron and steel (lbs.)	23,433	3,415	—	—	148,251
Riprap (cu. yds.)	—	—	—	—	822
Paving (cu. yds.)	—	—	—	—	21

*Included in item, "Earth excavation in open cut."

Electric power for all contract requirements was purchased by the contractor. The total consumed at the different shafts during the year was as follows:

	K.W.H.
Shaft 9	284,800
Shaft 10	1,824,800
Shaft 11	1,052,400
Shaft 11A	2,100
Shaft 12	895,800
Total	4,059,900

The total electrical power consumed on Contract 20 from beginning of work on April 23, 1931, to November 30, 1934, was approximately 23,107,570 kilowatt hours, the total length of tunnel excavated being 54,831 linear feet and the total length of tunnel lined being about 53,774 linear feet.

Quabbin Reservoir Division — Enfield Office

The Quabbin Reservoir Division continued in charge of the field work in the Swift River valley in connection with the proposed Quabbin Reservoir including topographic and real estate surveys, cemetery removal work, and the soil testing and water analysis laboratories. This division also continued in charge of construction work at the dike site, of the construction of exploratory caissons at the main dam site, of the construction of the Belchertown-Pelham highway and its extensions and of the relocation of the high-tension transmission line of the New England Power Company.

Miscellaneous Office Work

Semi-monthly estimates for Contracts 36, 41 and 44, monthly estimates for Contracts 23, 40 and 43, and the final estimate for Contract 40 were prepared. The preparation of real estate plans along the line of the new highway west of the reservoir was continued. Revised topographic plans of the main dam site and its vicinity were made. Photographs of the progress of construction carried on under the supervision of this and other divisions were taken. Meteorological records at Enfield were continued.

Miscellaneous Field Work

Lines and grades were given for construction on Contracts 23, 36, 40, 41, 43 and 44. A detailed topographic survey was made of the areas at the site of the spillway and spillway channel east of the main dam and of other areas in this vicinity. At the main dam the sites of the spillway and of its approach and discharge channels and other adjacent areas were cleared. Pumping from exploratory caisson 20 at the main dam site was continued until May 1 when it was taken over by the contractor sinking the caissons at the dike site, who was ordered to sink two additional exploratory caissons at the main dam site. The extension of the 24-inch discharge line to carry the pumpage from the exploratory caissons to a point above the upstream cofferdam was continued to completion and put in service December 15, 1933. Daily readings of the ground water level in numerous test wells were continued during the pumping operations at the dike and the dam. Sub-surface investigations were made by test pits in areas available for borrow for the dike embankment and for the east branch baffle. A cableway was installed across the approach channel to the stream control tunnel for the purpose of gauging the flow of the Swift River at this point. A log boom was placed across the entrance to the approach channel and following heavy rains the diversion tunnel was inspected and cleared of any accumulated debris. Repairs were made to the heating system of the Commission's garage in Enfield. The Department of Public Works continued its use of the garage for storage of equipment.

Along the new highway west of Quabbin Reservoir vistas for broad views were cleared and debris removed from the brook channels leading to culverts under the highway.

Surveys were made of various existing water supplies in Enfield and a labor force was employed on repairs to the same. Alterations were made to the field office at the main dam site constructed under Contract 30 to prepare it for use by the Dam and Aqueduct Division.

Reservoir — General

Topography. — Very little progress was made during the year on the general topographic maps within and adjacent to the proposed reservoir. To date 28,884 acres or 45.2 square miles have been surveyed. In the spillway location northeast of the main dam, detailed topographic surveys were made and maps plotted with 2-foot contour intervals. About 1.4 miles of the Swift River watershed divide was surveyed in addition to the 11.9 miles surveyed by the Coldbrook-Swift Tunnel Division, making a total to date of 13.3 miles.

Real Estate. — Properties described in applications by owners for sale of real estate was located and when no surveys had been made sketches showing the approximate location were prepared. Comprehensive real estate surveys and analyses and descriptions of deeds were continued. Real estate surveys during the year cover 479 acres, making a total to date of 60,001 acres or 93.75 square miles. Of this total 58,260 acres have been plotted at a scale of 1 inch = 200 feet. No additional final tracings were made.

Photography. — The photographing of buildings and cemetery lots within the area to be affected by the proposed reservoir were continued. During the year 60 photographs of buildings, 43 of cemetery lots and 212 of the progress of construction carried on under the supervision of this and other divisions were taken. Also 68 photographs of property in the Ware River watershed were taken.

Cemetery Removals. — Interments in Quabbin Park Cemetery and the general removal of bodies from existing cemeteries in the reservoir area were continued. The removal of bodies, headstones and monuments has been done with labor engaged directly for this work. During the year work progressed as shown in the following table:

CEMETERY REMOVALS

		To Nov. 30, 1933†	Year Ending Nov. 30, 1934	Total
Burial lots in Quabbin Park Cemetery assigned in exchange		407	34	441
Burial lots in Quabbin Park Cemetery sold		10	5	15
Number of releases executed of rights in old lots in Quabbin Reservoir area	to Q.P. Cemetery	126	86	212
	to other cemeteries	130	6	136
Bodies removed from Quabbin Reservoir area	to Q.P. Cemetery	651	475	1,126
	to other cemeteries	768	18*	786*
Bodies removed from Area outside Quabbin Reservoir to Quabbin Park Cemetery		—	2*	2*
Burials, not reinterments, in Q. P. Cemetery		30	24	54
Headstones moved	to Q. P. Cemetery	417	255	672
	to other cemeteries	355	7	362
Monuments moved	to Q. P. Cemetery	68	53	121
	to other cemeteries	129	2	131

†Quabbin Park Cemetery was not completed ready for use until August 25, 1932, prior to which time 632 bodies had been removed to other cemeteries.

*One body was originally moved outside and then back to Q. P. Cemetery and is included in this figure.

The vault was maintained in readiness for use during the winter months. Work of developing Quabbin Park Cemetery was continued by grading and seeding miscellaneous areas outside the established lots and by miscellaneous clearing and grubbing where trees interfered with the setting of stones. Cemetery lots were graded and seeded as removals were completed and in the case of purchases were graded and seeded at once. The average force employed on cemetery development during the working operations was 13 men, the maximum being 16 during the week ending June 6.

Fire Protection. — The fire fighting equipment was continued in readiness for service at all times. Five assistants in the division office were reappointed as deputy forest wardens in each of the towns affected by the reservoir. The equipment and personnel responded during the year to calls for assistance at 13 forest fires which burned over a total area of 247.75 acres. The apparatus also responded to fires in 14 buildings, 12 of which were chimney fires resulting in little if any damage.

Clearing. — The construction of the dike embankment under Contract 50 will necessitate the early diversion of Beaver Brook northerly to the Swift River and the consequent flooding of a considerable area upstream from the dike site. In anticipation of this diversion an area of approximately 140 acres was cleared of all standing timber, brush and refuse. With the exception of a considerable area on the east side of the brook the clearing was done by a labor force which reached a maximum of 35. The work was started June 26 and practically completed October 12. Three hundred cords of cordwood were salvaged and piled near the main highway and pine timber was sold. An area on the east side of the brook was cleared by labor supplied by the ERA of the Town of Ware, which work commenced July 9 and was completed November 15 with a maximum force of 76.

Lumbering. — Under an agreement with the New England Box Company,

dated January 4, for the purchase of standing timber, this company started cutting operations January 17 and continued throughout the year with a maximum of four mills in operation. The lumber was stacked as cut and hauling away commenced August 1 and continued throughout the year. At the end of the year about 4,420,000 Ft. B.M. had been cut, and about 1,528,000 Ft. B.M. had been hauled.

Soil Testing Laboratory. — The work of exploring, collecting and testing materials, and the washing of materials in the experimental sluicing bin, to determine their suitability for use in the construction of the proposed main dam and dike and other structures was continued. New equipment was added to the laboratory as testing methods were expanded to include new studies and to keep pace with current developments in soil engineering. Investigations were continued of the glacial deposits in prospective borrow areas on both sides of Beaver Brook valley north of the dike site and of the Swift River north of the main dam site. Similar investigations were made of materials at the suggested site for the east-branch baffle at Greenwich Village. Tests were continued of top soils for impervious refill particularly in connection with the work under Contract 36. The latter included routine control tests for permeability, density, moisture and organic material, and the use of the plasticity needle. Tests were continued of concrete aggregates, concrete and other miscellaneous materials used in the construction work of this and other divisions.

Chemical and Bacteriological Laboratory. — The collecting and analyzing of water samples were continued in cooperation with the headquarters office and with assistants from the Coldbrook-Swift Tunnel Division and included also the analysis of industrial wastes. Samples of the water supplies of contractors engaged on work in this and other divisions and of miscellaneous supplies on property controlled by the Commission were collected and analyzed periodically.

Progress of Contracts

Contract 23. — Contract 23, for making borings in the towns of Belchertown, Enfield, Ware, Greenwich and Hardwick, continued in force throughout the year. The work consisted principally of the exploration of proposed borrow areas for materials to be used in construction, of explorations in the vicinity of the east spillway site and spillway channel and of the sinking of wells for the observation of ground water levels at the main dam site.

The value of work included in contract estimates during the year was $8,919.41 or a total to November 10, the date of the latest estimate, of $51,712.57, of which 90% was approved for payment. The contractor had one drilling rig in operation during the year and employed an average of two men.

Contract 35. — Contract 35, with the New England Power Company, for the purchase of electricity for experimental work at the dam site, was continued in force throughout the year. The contract was amended to permit the taking of power for future pumping at larger capacity from all three exploratory caissons. Electric power was purchased for use in experimental pumping from caisson 20. The total power furnished was 430,860 kilowatt hours, costing $7,972.30, during the year.

Contract 36. — Contract 36, for constructing a core wall to sound rock at the site of the dike of Quabbin Reservoir in the towns of Enfield and Ware, continued in force throughout the year. The sinking of caissons continued by the method previously reported and the remaining 14 caissons were completed, sunk and sealed to sound rock, the last caisson being sealed March 24. The total depth of sinking of caissons below the ordered bottom of the open-cut trench was 2,013 feet not including a total of 336 feet of underpinning below the cutting edge after sinking stopped. Of this total, 1,496 feet was by open excavation and 517 feet under compressed air, in addition to the underpinning under compressed air. The ground water was lowered to such an extent that although the maximum depth of sinking below the original ground water level was 130 feet, the maximum pressure was only 25 lbs. per square inch, at the bottom of caisson number 10, near the deepest point in the rock gorge.

The construction of end joints between the caissons was continued by the method previously reported and the remaining 18 end joints were excavated and sealed,

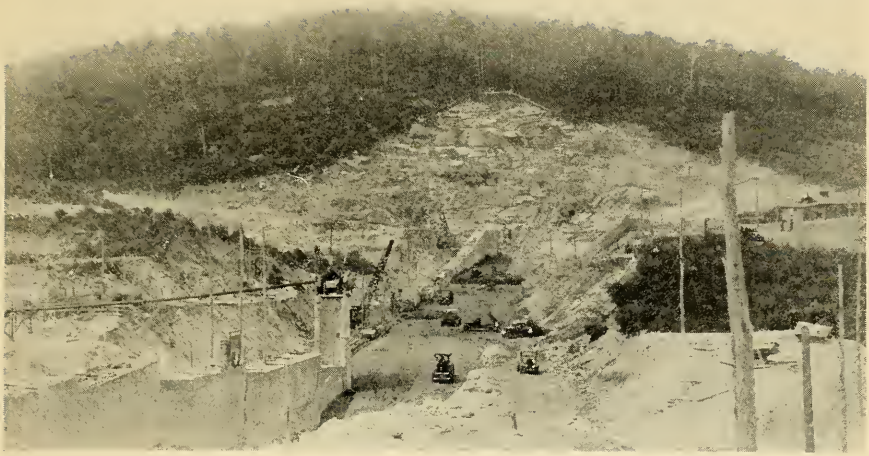
the last end joint being sealed May 23. To complete the westerly end a short length of core wall was constructed in open trench. The bedrock wall of the valley rises very steeply at this point and considerable loose, scaly and heavily-seamed rock was removed and a concrete mat was constructed on the ledge to an elevation somewhat above the required refill of impervious material. Grouting through the bottoms of the sealed caissons was continued to completion in the manner previously described and extended to the limit of the concrete mat at the westerly end of the core wall.

Following the completion of the sinking of caissons, concrete was added to the top of all low caissons to make a continuous wall 25 feet above the bottom of the open-cut trench at all points. One end of caisson 7 was extended by a concrete shaft carried up to an elevation above the top of the impervious refill so that access could be had to pumps in this caisson as well as to those in the high caisson numbered 13, which was sunk from the original surface as an exploratory caisson under Contract 32.

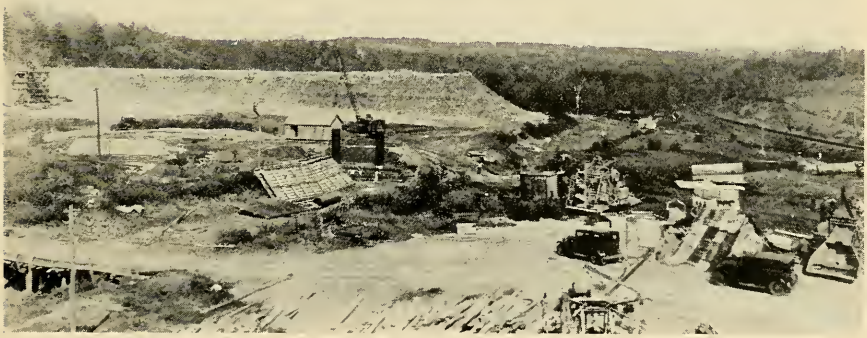
The shafts of all caissons, except the high shaft in caisson 7, and one shaft in caisson 13 reserved for access as above described, were filled to their tops with impervious material consisting of carefully selected top soil thoroughly tamped by means of a concrete cylinder attached to a cable and hoisting engine and repeatedly dropped during placing of the material. The open trench was trimmed to grade and refilled around and over the tops of the caissons with impervious material to an elevation which would permit natural drainage into Beaver Brook. The impervious refill consisted of selected top soil placed in 6-inch layers and compacted by rolling with a 14-ton banded roller. The top soil was excavated by a power shovel hauled to the dike in 2-cubic yard dump trucks and spread by bulldozers. At points inaccessible to the roller, consolidation was effected by hand tamping. To keep the ground water level down during the operations pump suction inlets were provided in the bottom of caissons 4, 7, 10, 13 and 16 and the water was pumped at various times from these points. Pumping from chambers of other caissons was also done during the sinking operations. As the fill reached the tops of the various caissons, pumping was discontinued, the suction intakes grouted and the wells sealed. A pipe line was placed through the cofferdams and the core wall to carry the flow of Beaver Brook past the site until its waters are diverted northerly to the Swift River. At the end of the year practically all the work at the dike site was completed except for a small amount of stripping and impervious filling.

Exploratory Caissons at Main Dam. — On April 13, the contractor was ordered to sink two additional exploratory caissons at the main dam site near the old river bed where the depth to sound ledge was the greatest. These caissons were sunk and equipped for pumping from suction intakes beneath the cutting edge on both upstream and downstream sides just above the ledge in order that the experimental pumping from caisson 20, sunk under Contract 32, could be extended to effectively lower the ground water level over the entire valley floor. These two exploratory caissons, constructed of the same design as those at the dike, were 45 feet long and 9 feet wide. They were located so as to become a part of a future core wall at the main dam similar in all respects to that at the dike. The sinking of these caissons was expedited by pumping from the working chamber of one caisson while the other was being sunk and by continuous pumping from small intakes in the side walls of the first exploratory caisson, numbered 20, which, although of small capacity and located at a considerable distance from the river bed, had already lowered the ground water level 10 feet at the river bed. The maximum air pressure used for a brief period at the bottom of these two caissons was 37½ lbs.

At the end of the year these caissons had been sealed to bedrock, and suction intakes of ample capacity installed in the concrete seals below the cutting edge. The porous condition of the ground in the immediate vicinity of the bottom of caisson 7 was found to be much more favorable to a high pumpage rate than in the case of caisson 9. At the end of the year the original caisson, numbered 20, was delivering about 900 gallons per minute, number 7, about 3,100 gallons per minute and number 9, about 1,000 gallons per minute, a total of about 5,000 gallons per minute. Observations on the resulting lowering of the ground water level indicate that it will be possible to construct the entire caisson cut-off wall at relatively low air pressure and reduced cost. Caisson 7 was sunk 104 feet and caisson 9, 108 feet



Contract 36. — Dike Core Wall, Placing Impervious Refill in the Open-Cut Trench Around and Over the Projecting Tops of the Caissons. View Looking West.



Contract 36. — Main Dam Core Wall, Starting Two Exploratory Caissons at Main Dam Site. Old River Bed and Railroad Pass through Gap in Upstream Cofferdam.

to what borings indicate is the deepest point of the rock gorge. The maximum depth reached in the underpinning was 122 feet below the old river bed.

The value of work included in contract estimates during the year was $429,-698.20, or a total to November 20, the date of the latest estimate of $1,103,513.15, of which 90% was approved for payment. The contractor's force averaged 121 men, the maximum being 187 on August 21. The average number of persons occupying the camp at the dike site was 13, the maximum population being 24 during the week ending August 4, when the contractor's camp closed.

No important items of plant were added during the year except one 1-cubic yard concrete mixer on tractor treads and one aggregate unloader.

The total work done and materials furnished to date under the principal items of Contract 36 are as follows:

Earth excavation in open cut to elevation 400	227,600 cu. yds.
Earth excavation in open cut below elevation 400	47,500 " "
Rock excavation as boulders in open cut	1,440 " "
Rock excavation as ledge in open cut	3,800 " "
Stripping	62,000 " "
Unconsolidated embankment	29,000 " "
Consolidated pervious embankment	221,500 " "
Rolled impervious embankment	106,000 " "
Pumping	229,300 mil. ft. gals.
Earth excavation for core wall, bottom of open cut to elevation 310	29,800 cu. yds.
Earth excavation for core wall below elevation 310	1,960 " "
Rock excavation in caissons to elevation 310	2,015 " "
Rock excavation in caissons below elevation 310	1,045 " "
Concrete not placed under air pressure	38,820 " "
Concrete placed under air pressure	5,100 " "
Impervious filling in caisson shafts	3,200 " "
Drilling holes in rock or masonry	9,800 lin. ft.
Furnishing and placing grout	520 cu. yds.
Portland cement	72,595 bbls.
Riprap	4,490 cu. yds.

Contract 40. — Contract 40, for the removal and relocation of transmission and telephone lines and substation, in the towns of New Salem, Belchertown, Enfield and Ware, was continued to completion. The 22,000-volt line was completed December 8, 1933. The telephone line on the 22,000-volt alignment was completed December 11. On December 17, the second circuit of the 66,000-volt line was energized and permanent connections made on the 22,000-volt line with the Belchertown tap. All work on the 66,000-volt line was completed January 11. The work of raising towers and protecting their footings with embankment fill and riprap on the 110,000-volt line in New Salem was completed January 12.

The value of work included in contract estimates during the year was $86,744.00 the final estimate dated February 15 being for $104,790.10, and the total including damages, $154,790.10. The contractor's force averaged 34 men to January 26, the maximum being 57 for the week ending December 16, 1933.

Contract 41. — Contract 41, for constructing a portion of the Belchertown-Pelham highway in the towns of Belchertown and Pelham, Hampshire County, continued in force throughout the year. Construction work was carried on through the winter until February 20 and then closed down until April 20 when it was again resumed. The work during the winter was confined to earth and ledge excavation, placing gravel base and laying pipe culverts in the vicinity of the Pelham-Shutesbury town line where considerable water had been encountered in the excavations. The frozen ground expedited the contractor's operations in truck hauling. Construction of the macadam surface was resumed May 4 about ¼ mile north of the Belchertown line in Pelham and continued northerly to completion. Broken stone was hauled by truck from a quarry in Amherst. The base course 4½ inches thick was formed by a power grader and then "spotted" by hand to the true surface. This course was rolled with a 12-ton gasoline or steam roller, bound with sand and again rolled. The top course 2 inches thick was similarly placed and rolled without the sand binder. Asphalt penetration was at the rate of 2⅛ gals. per sq. yd. on all grades less than 3%. The surface was then covered with pea stone, broomed and rolled. On grades less than 3% a seal coat of asphalt was applied at the rate of ⅜ gals. per sq. yd., another application of pea stone made, and the surface given its final rolling. On grades of 3% or over asphalt penetration was applied at the rate of 2½ gals. per sq. yd. with no seal. Inspection of the

stone surfacing and asphalt applications was made by the District Engineer's Office of the Department of Public Works.

Loam berms were constructed on the shoulders on the inside of banked curves and on steep grades on fills, to prevent erosion of embankments, and cobble gutters treated with asphalt were installed to carry the drainage down the slopes of fills and at other critical points. In general, slopes in cuts were protected by the construction of ditches back of the top of the slope. Considerable loaming and seeding was done on wet slopes to prevent slides onto the highway. The embankment was widened at various places to permit parking of automobiles at scenic outlooks. The work was completed November 20.

The value of the work included in contract estimates to November 16, the date of the latest estimate, was $228,423.63, of which $117,651.00 was assumed by the Department of Public Works, covering surfacing items. Of the remaining $110,772.63, $106,280.34 was approved for payment. The contractor's force averaged 46 men, the maximum being 77 during the week ending August 25. There were no additions to plant items.

The total work done and materials furnished under the principal items of Contract 41 are as follows:

Roadway earth excavation	110,700 cu. yds.
Ledge excavation	17,235 " "
Ordinary borrow	65,750 " "
Gravel borrow	54,750 " "
Loam borrow	8,350 " "
Plain cement concrete masonry	375 " "
Reinforced concrete masonry	123 " "
Broken stone	51,000 tons
Bituminous material	328,000 gallons
Cable guard rail	26,600 lin. ft.

Contract 43. — Contract 43, for constructing an extension of the Belchertown-Pelham highway to New Salem Center in the towns of Shutesbury and New Salem, Franklin County, continued in force throughout the year. This road is of the same type as built under Contract 41. Construction work was closed down for the winter on December 23, 1933, and resumed on March 30. One 8′ x 8′ reinforced concrete double box culvert and one 8′ x 8′ single box culvert were constructed at the crossing of the west branch of the Swift River. Broken stone was delivered by rail to New Salem and hauled by truck from the railroad siding. Placing broken stone was started June 11 and completed October 24. The base course was 4 inches thick bound with sand and the top course 2½ inches thick. On three heavy fills the bottom course of broken stone was omitted and a 3-inch layer of top stone placed on the gravel base to permit a possible later application of stone if settlement should occur. Asphalt penetration was started June 25 and all work of penetrating and sealing was completed October 29. Inspection of the stone surfacing and asphalt applications was made by the District Engineer's Office of the Department of Public Works.

Loam berms and asphalt treated cobble gutters were constructed and side slopes in cut were loamed and ditched back of top of slopes the same as above described in the case of Contract 41. Two particularly wet slopes near Cooleyville were underdrained by 4-inch vitrified pipe laid in trenches and backfilled with porous material. On several very wet slopes on the southerly end of the road, blind drains were installed to increase their stability and prevent slides. At the end of the year the work was practically completed except the installation of guard rail which was about 75% completed.

The value of work included in contract estimates to November 26, the date of the latest estimate was $295,640.57, of which $101,371.50 was assumed by the Department of Public Works, covering surfacing items. Of the remaining $194,269.07, $156,388.37 was approved for payment. The contractor's force averaged 56 men, the maximum being 87 for the week ending September 22.

The principal items of plant were as follows:

8 Gasoline shovels
4 Bulldozers
4 Road rollers
1 Road grader
2 Stone spreaders
3 Tractors
4 Compressors

The total work done and materials furnished to date under the principal items of Contract 43 are as follows:

Roadway earth excavation	224,900 cu. yds.
Ledge excavation	24,150 " "
Ordinary borrow	20,900 " "
Gravel borrow	72,050 " "
Loam borrow	11,000 " "
Plain cement concrete masonry	390 " "
Reinforced concrete masonry	347 " "
Broken stone	43,065 tons
Bituminous material	267,600 gallons
Cable guard rail	27,900 lin. ft.

Contract 44. — Contract 44, for constructing an extension of the Belchertown-Pelham highway north of New Salem Center in the towns of New Salem and Orange, Franklin County, continued in force throughout the year. This road is of the same type as built under Contracts 41 and 43. At the beginning of the year the only work done was clearing. In spite of severe weather conditions the contractor continued his operations throughout the winter. One 7′ x 9′ reinforced concrete double box culvert at the crossing of the middle branch of the Swift River, one 5′ x 4′ single box culvert 132 feet long at the crossing of Moosehorn Brook and one 4′ x 4′ single box culvert 95 feet long at a crossing south of Moosehorn Brook were constructed. At the crossing of the middle branch of the Swift River deposits of soft silt up to 28 feet in depth were removed by dynamite. For blasting the mat of stumps and roots on the surface of the swamp, dynamite was placed in holes 18 inches apart in rows 4 feet apart. To provide a space for material to be displaced from beneath the fill, a narrow area outside the foot of the slope of the completed fill was blasted with dynamite placed in holes 4 feet on centers. The fill was then placed over the area where the mat had been blasted, pushing soft material ahead and to the sides, to a depth equal at least to that of the underlying soft material to be displaced. Four-inch pipes spaced 12 feet on centers were then driven through the fill to within 2 feet of the bottom of the material to be displaced. These pipes were first sprung with ½ pound of dynamite each in order to free the bottom of the pipe and then loaded with the charge. Where necessary this process was repeated until the fill reached a firm bottom. About 12,000 pounds of dynamite were used.

Broken stone was delivered by rail to Orange and hauled by truck from the railroad siding. Placing broken stone was started July 25 and the entire surface completed October 2. All stone was placed by use of a box spreader, the base course being 4½ inches thick and the surface course 2 inches thick. On two heavy fills the bottom course of broken stone was omitted and a 3-inch layer of stone placed on the gravel base to permit a possible later application of stone if settlement should occur. Inspection of the stone surfacing and asphalt applications was made by the District Engineer's Office of the Department of Public Works.

Loam berms and asphalt-treated cobble gutters were constructed and side slopes in cut were loamed and ditched back of top of slope where deemed desirable the same as in Contracts 41 and 43. The work was completed November 20.

The value of work included in contract estimates to November 5, the date of the latest estimate, was $182,848.76, of which $62,210.80 was assumed by the Department of Public Works, covering surfacing items. Of the remaining $120,637.96, 85% was approved for payment. The contractor's force averaged 39 men, the maximum being 94 on August 24.

The principal items of plant were as follows:

3 Gasoline shovels
3 Bulldozers
3 Stone spreaders
4 Road rollers
2 Road graders
2 Compressors
An average of 7 trucks, 2½ to 5 tons.

The total work done and materials furnished to date under the principal items of Contract 44 are as follows:

Roadway earth excavation	130,450 cu. yds.
Ledge excavation	21,045 " "
Gravel borrow	27,050 " "
Loam borrow	9,000 " "

Plain cement concrete masonry	200 cu. yds.
Reinforced concrete masonry	330 " "
Broken stone	23,000 tons
Bituminous material	155,950 gallons
Cable guard rail	18,610 lin. ft.

Geological Data

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State." Such information is being prepared for publication in a subsequent report.

List of Drawings and Tables Appended Hereto

Location of Real Estate Acquired for Quabbin Reservoir.
Takings of Real Estate (and Water Rights).
Status of Contracts Completed between Nov. 30, 1933, and Nov. 30, 1934; and in force on November 30, 1934.
Canvass of Bids; Contract 50.

For data on Contracts Completed Prior to Nov. 30, 1933, see Sixth, Seventh and Eighth Annual Reports. A General Plan of the Metropolitan Water Supply and plans and profile of the Quabbin Aqueduct Tunnel have been published in previous reports.

Respectfully submitted,

Frank E. Winsor, *Chief Engineer.*

20 Somerset Street, Boston, Mass.
December 27, 1934.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

New accounts have been opened during the year necessitating transfers from old accounts.

General Overhead

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Administration, *Commissioners' Office:*		
Salaries, Commissioners	$9,586.11	$85,915.57
Salaries, Clerical	12,057.42	84,766.90
General Legal Expense	125.00	1,502.80
Furniture and Fixtures	351.18	2,809.55
Rent and Upkeep	2,242.28	18,154.67
Automobile Purchase	0.00	2,464.90
Automobile Maintenance	248.41	2,472.89
Miscellaneous Expense (undistributed)	938.60	11,949.47
Advertising	484.95	6,140.95
Printing and Blueprinting	1,381.11	8,451.12
Stationery and Office Supplies	243.26	1,843.21
Postage	185.05	997.30
Total Administration, Commissioners' Office	$27,843.37	$227,469.33
Engineering, *Headquarters' Office:*		
Salaries, Engineering	$72,085.55	$619,217.48
Salaries, Clerical	8,692.37	73,961.20
General Consultant Expense	1,360.53	116,515.25
General Legal Expense	0.00	53,160.29
Furniture and Fixtures	511.24	13,750.14
Laboratory Equipment	0.00	1,961.00
Laboratory Supplies	0.00	2,071.94
Rental of Equipment	0.00	3,370.02
Engineering Instruments	29.59	1,082.63
Rent and Upkeep of Boston Office	10,097.70	83,379.76
Rent and Upkeep of Springfield Laboratory	0.00	3,950.54
Automobile Purchase	0.00	3,151.60
Automobile Maintenance	248.48	3,362.26
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	675.80	20,109.18
Printing and Blueprinting	330.36	13,387.13
Stationery and Office Supplies	516.53	4,576.73
Postage	198.00	1,531.58
Total Engineering, Headquarters' Office	$94,746.15	$1,020,843.36
Unassigned:		
Unassigned Supplies and Equipment	$-9.21	$563.42
Total Unassigned	$-9.21	$563.42
Total General Overhead	$122,580.31	$1,248,876.11

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Distribution of General Overhead		
Administration, *Commissioners' Office:*		
Wachusett-Coldbrook Tunnel	$3,000.36	$72,679.91
Coldbrook-Swift Tunnel	3,642.28	21,826.12
Quabbin Reservoir	6,428.97	85,140.64
Main Dam	6,032.98	18,385.19
Beaver Brook Dike	8,738.78	20,747.19
Southern Sudbury Emergency Supply	0.00	8,690.28
Total Administration, Commissioners' Office	$27,843.37	$227,469.33
Engineering, *Headquarters' Office:*		
Wachusett-Coldbrook Tunnel	$9,767.88	$293,559.60
Coldbrook-Swift Tunnel	12,093.90	87,208.74
Quabbin Reservoir	22,762.97	460,323.35
Main Dam	19,521.75	67,509.28
Beaver Brook Dike	30,599.65	78,834.42
Southern Sudbury Emergency Supply	0.00	33,407.97
Total Engineering, Headquarters' Office	$94,746.15	$1,020,843.36
Wachusett-Coldbrook Tunnel Section of Quabbin Aqueduct, Ware Supply		
General Overhead:		
Administration	$3,000.36	$72,679.91
Engineering	9,767.88	293,559.60
Total General Overhead	$12,768.24	$366,239.51
Engineering:		
Salaries, Engineering and Clerical	$5,070.79	$392,890.37
Consultant Expense	0.00	7,612.36
Labor	218.13	2,009.33
Furniture and Fixtures	0.00	2,240.89
Engineering Instruments	13.80	7,755.47
Rent and Upkeep	2,015.76	16,772.22
Automobile Purchase	22.85	11,265.82
Automobile Maintenance	396.45	15,098.18
Contracts for Investigations and Surveys	0.00	18,640.69
Miscellaneous Expense (undistributed)	263.85	9,178.35
Advertising	0.00	6.05
Printing and Blueprinting	110.22	1,057.87
Stationery and Office Supplies	238.95	2,963.03
Postage	41.17	434.81
Total Engineering	$8,391.97	$487,925.44
Real Estate, *General Construction:*		
Legal and Expert Expense	$197.00	$5,849.66
Consultant Expense	0.00	455.66
Labor	451.20	1,624.50
Miscellaneous Expense (undistributed)	156.85	1,003.60
Printing and Blueprinting	5.24	50.38
Purchases and Settlements	1,450.00	122,989.16
Taxes	185.50	3,265.67
Maintenance of Real Estate	371.11	993.94
Police Protection, Labor	10.00	41.00
Fire Protection Equipment	0.00	30.97
Miscellaneous Expense	0.54	0.54

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Special Agents, Salaries	$0.00	$12,949.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	0.00	1,222.50
Automobile Maintenance	0.00	2,124.30
Miscellaneous Expense (undistributed)	0.00	1,201.73
Printing and Blueprinting	0.00	26.51
Stationery and Office Supplies	0.00	5.48
Postage	0.00	21.36
Total Real Estate	$2,827.44	$153,973.63
Ware Watershed Protection:		
Salaries, Engineering and Clerical	$33,160.02	$100,603.46
Legal and Expert Expense	1,531.30	14,712.54
Consultant Expense	0.00	763.70
Labor	383.00	9,258.24
Engineering Instruments	163.15	289.25
Contract No. 27, Swamp Improvement above Ware River Intake	0.00	4,395.51
Contract No. 39, Rutland-Holden Sewer	142,109.74	192,523.91
Automobile Purchase	0.00	543.95
Automobile Maintenance	1,599.53	3,165.90
Special Experiments	700.00	700.00
Miscellaneous Expense (undistributed)	924.63	4,325.60
Printing and Blueprinting	55.06	458.07
Stationery and Office Supplies	29.99	92.34
Installed Equipment	1,292.86	5,452.56
Purchases and Settlements	37,067.48	1,056,245.49
Taxes	2,341.11	19,426.41
Maintenance of Real Estate	36.40	176.41
Special Agents, Salaries	2,268.67	2,268.67
Automobile Maintenance	509.68	509.68
Miscellaneous Expense (undistributed)	257.91	257.91
Stationery and Office Supplies	1.15	1.15
Postage	6.00	6.00
Rutland-Holden Sewer, Maintaining, Cleaning and Repairing		
State Sanatorium Branch	12.11	12.11
U. S. Vet. Hospital Branch	17.72	17.72
Trunk Sewer, except Branches	16.68	16.68
Total Ware Watershed Protection	$224,484.19	$1,416,223.26
Ware Diversion Damages — Except Jury Trials:		
Salaries, Engineering and Clerical	$14,169.11	$84,648.77
Legal and Expert Expense	549.32	3,099.33
Consultant Expense	−2,028.25	27,858.59
Labor	72.36	2,279.24
Furniture and Fixtures	0.72	24.16
Laboratory Equipment	28.99	150.14
Laboratory Supplies	93.80	209.71
Engineering Instruments	0.94	511.94
Rental of Equipment	6.00	203.75
Automobile Purchase	0.00	145.38
Automobile Maintenance	739.17	3,034.93
Contracts for Investigations and Surveys	0.00	63.27
Materials of Construction	0.00	136.51
Miscellaneous Expense (undistributed)	−66.27	6,962.93
Printing and Blueprinting	550.35	1,077.82

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Stationery and Office Supplies	$5.37	$24.28
Postage	0.00	6.62
Purchases and Settlements	41,750.00	165,225.00
Sub Total Ware Diversion Damages — Except Jury Trial	$55,871.61	$295,662.37
WARE DIVERSION DAMAGES — JURY TRIAL:		
Salaries, Engineering and Clerical	$13,226.69	$13,226.69
Legal Expense	11,076.13	11,076.13
Consultant Expense	15,222.56	15,222.56
Expert and other Witness Expense	10,541.97	10,541.97
Automobile Maintenance	44.36	44.36
Miscellaneous Expense	1,689.80	1,689.80
Settlements for less than Jury Verdicts	260,000.00	260,000.00
Sub Total Ware Diversion Damages — Jury Trial	$311,801.51	$311,801.51
Total Ware Diversion Damages	$367,673.12	$607,463.88
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Completed Contracts Nos. 4, 8, 10, 12, 14, 17, 18, 19, 22, 24, 25, 26, 28, 29, 31	$0.00	$9,629,739.99
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$25.87	$59,018.10
Temporary Equipment	0.00	6,423.60
Labor	546.92	3,633.24
Contracts for Equipment for Surveys	0.00	898.34
Maintenance of Partially Completed Structures	1,156.10	7,445.59
Maintenance of Grounds	530.93	2,786.29
Purchases of Plants, Trees and Shrubbery	11.76	842.58
Rental of Equipment	0.00	7.00
Miscellaneous Expense	0.00	9,453.84
Total	$2,271.58	$90,508.58
Total Wachusett-Coldbrook Tunnel, Ware Supply	$618,416.54	$12,752,074.29
SPECIAL INVESTIGATION — POLLUTION OF WARE AND QUINAPOXET WATERSHEDS (Expenditures under Chapter 66, Resolves of 1931)		
Total Special Investigation	$0.00	$1,995.99
COLDBROOK-SWIFT TUNNEL SECTION OF QUABBIN AQUEDUCT		
GENERAL OVERHEAD:		
Administration	$3,642.28	$21,826.12
Engineering	12,093.90	87,208.74
Total General Overhead	$15,736.18	$109,034.86
ENGINEERING:		
Salaries, Engineering and Clerical	$53,331.87	$212,775.94
Consultant Expense	78.22	334.12
Labor	0.00	536.25
Furniture and Fixtures	8.33	770.91
Engineering Instruments	130.73	4,537.70
Rent and Upkeep	1,227.98	9,026.96
Automobile Purchase	707.55	8,135.52
Automobile Maintenance	1,743.48	15,485.39
Contracts for Investigations and Surveys	0.00	13,525.66
Materials of Construction	0.00	2.25

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Miscellaneous Expense (undistributed)	$524.66	$7,337.47
Printing and Blueprinting	170.86	810.73
Stationery and Office Supplies	192.74	1,998.79
Postage	88.90	444.56
Total Engineering	$58,205.32	$275,722.25
REAL ESTATE:		
Legal and Expert Expense	$44.05	$3,084.37
Labor	0.00	12.20
Miscellaneous Expense (undistributed)	0.00	27.16
Printing and Blueprinting	0.00	34.87
Postage	0.00	5.68
Purchases and Settlements	260.00	22,585.00
Taxes	170.78	467.29
Maintenance of Real Estate	0.00	24.85
Fire Protection, Equipment	0.00	60.86
Total Real Estate	$474.83	$26,302.28
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 20, Construction of Coldbrook-Swift Tunnel	$806,569.55	$4,444,062.05
Total Contracts	$806,569.55	$4,444,062.05
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$0.00	$64.75
Installed Equipment	25.77	117.64
Miscellaneous Expense	1,083.87	2,358.16
Total	$1,109.64	$2,540.55
Total Coldbrook-Swift Tunnel	$882,095.52	$4,857,661.99
QUABBIN RESERVOIR EXCEPT MAIN DAM AND DIKE		
GENERAL OVERHEAD:		
Administration	$6,428.97	$85,140.64
Engineering	22,762.97	460,323.35
Total General Overhead	$29,191.94	$545,463.99
ENGINEERING:		
Salaries, Engineering and Clerical	$30,449.63	$312,917.74
Consulting Expenses	228.23	228.23
Labor	1,682.70	7,218.69
Furniture and Fixtures	59.65	3,017.03
Laboratory Equipment	532.91	1,010.31
Laboratory Supplies	1,013.87	1,935.35
Rental of Equipment	0.00	16.75
Engineering Instruments	127.38	6,402.28
Rent and Upkeep	1,756.48	7,046.03
Automobile Purchase	–1,800.00	15,036.39
Automobile Maintenance	1,337.12	13,129.65
Special Experiments	0.00	422.80
Contracts for Investigations and Surveys	1,473.75	12,068.54
Office Buildings	0.00	4,915.54
Miscellaneous Expense (undistributed)	605.74	4,738.40
Printing and Blueprinting	186.30	1,736.68
Stationery and Office Supplies	501.75	4,952.96
Postage	205.50	905.14
Total Engineering	$38,361.01	$397,698.51

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
REAL ESTATE — EXCEPT BOARD OF REFEREES AND JURY TRIAL:		
Legal and Expert Expense	$10,888.93	$143,689.23
Labor	0.00	95.35
Furniture and Fixtures	0.00	15.68
Miscellaneous Expense (undistributed)	689.42	5,551.27
Advertising	0.00	208.66
Printing and Blueprinting	183.43	1,286.80
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	427,232.46	5,897,535.96
Taxes	37,807.33	223,561.69
Maintenance of Real Estate	1,125.38	4,280.73
Water Supply System	24.60	40.60
Fire Protection Equipment	85.61	3,552.83
Automobile Purchase	0.00	771.69
Automobile Maintenance	15.00	257.14
Labor	0.00	27.20
Miscellaneous Expense	22.43	129.73
Police Protection, Labor	0.00	14.00
Special Agents, Salaries	2,268.67	15,566.00
Equipment	0.00	118.33
Automobile Purchase	0.00	1,236.96
Automobile Maintenance	363.28	2,717.79
Miscellaneous Expense (undistributed)	146.05	1,089.43
Printing and Blueprinting	0.00	41.60
Stationery and Office Supplies	0.00	9.33
Postage	2.40	13.62
Renting Agents, Salaries	2,600.67	18,068.10
Furniture and Fixtures	0.00	29.29
Miscellaneous Expense (undistributed)	62.25	485.96
Printing and Blueprinting	0.00	18.62
Stationery and Office Supplies	7.33	33.41
Postage	29.36	114.88
Payments to Towns	2,000.00	12,500.00
Sub Total Real Estate — Except Board of Referees and Jury Trial	$485,554.60	$6,333,062.33
REAL ESTATE — BOARD OF REFEREES:		
Salaries of Referees	$6,940.00	$6,940.00
Salaries, Engineering and Clerical	967.88	967.88
Legal Expense	4,124.96	4,124.96
Consultant Expense	622.40	622.40
Expert and other Witness Expense	4,510.07	4,510.07
Expenses of Board of Referees	550.30	550.30
Miscellaneous Expense	45.78	45.78
Sub Total Real Estate — Board of Referees	$17,761.39	$17,761.39
REAL ESTATE — JURY TRIAL:		
Salaries, Engineering and Clerical	$27.73	$27.73
Legal Expense	169.33	169.33
Sub Total Real Estate — Jury Trial	$197.06	$197.06
Total Real Estate	$503,513.05	$6,351,020.78
QUABBIN RESERVOIR DAMAGES:		
Salaries, Engineering	$0.00	$48.68
Legal and Expert Expense	–49.02	931.00

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Board of Referees	$–9.75	$0.00
Consultant Expense	0.00	2,158.82
Miscellaneous Expense	0.00	18.15
Purchases and Settlements	125.00	45,410.00
Total Quabbin Reservoir Damages	$66.23	$48,566.65
Swift Diversion Damages:		
Salaries, Engineering and Clerical	$10,405.25	$65,758.08
Legal and Expert Expense	1,304.21	5,582.83
Consultant Expense	11,765.57	61,363.34
Labor	64.44	138.14
Furniture and Fixtures	6.55	37.51
Laboratory Equipment	260.89	966.82
Laboratory Supplies	844.16	1,653.53
Engineering Instruments	8.41	740.61
Rental of Equipment	0.00	10.50
Automobile Purchase	0.00	1,308.41
Automobile Maintenance	721.66	2,134.92
Contracts for Investigations and Surveys	0.00	569.47
Materials of Construction	0.00	18.99
Miscellaneous Expense (undistributed)	558.95	5,937.87
Printing and Blueprinting	304.48	887.81
Stationery and Office Supplies	7.14	27.89
Purchases and Settlements	375,750.00	942,975.00
Total Swift Diversion Damages	$402,001.71	$1,090,111.72
Quabbin Reservoir — Cemeteries		
Quabbin Park Cemetery Construction:		
Salaries, Engineering and Clerical	$438.84	$11,144.27
Legal and Expert Expense	0.00	65.00
Consultant Expense	0.00	125.00
(Construction) Labor	2,386.44	10,987.35
Tools and Equipment	0.00	83.96
Automobile Purchase	0.00	1,615.37
Automobile Maintenance	84.14	1,066.75
Rental of Equipment	0.00	33.19
Purchases and Settlements	0.00	8,850.00
Construction Materials	88.68	1,554.21
Purchase and Planting of Trees and Shrubbery	0.00	218.93
Receiving Vault	0.00	2,768.85
Water Supply System	0.00	1,251.97
Maintenance of Grounds	1,485.03	3,316.26
Miscellaneous Expense (undistributed)	1.85	156.86
Printing and Blueprinting	1.50	159.08
Stationery and Office Supplies	0.00	9.03
Contract No. 34, Construction of Driveways	0.00	7,842.94
Sub Total Quabbin Park Cemetery Construction	$4,486.48	$51,249.02
Removals from Cemeteries within Reservoir Area to Quabbin Park Cemetery:		
Salaries, Engineering and Clerical	$1,889.25	$4,728.59
Tools and Equipment	0.00	412.14
Automobile Purchase	0.00	2,669.99
Automobile Maintenance	399.16	783.21

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Removal and Reinterment of Bodies	$2,926.00	$7,239.28
Removal and Resetting of Monuments	1,995.16	4,946.02
Miscellaneous Expense	0.00	2.00
Rental of Equipment	0.00	10.50
Sub Total Removals to Quabbin Park Cemetery	$7,209.57	$20,791.73
REMOVALS FROM CEMETERIES WITHIN RESERVOIR AREA TO CEMETERIES OTHER THAN QUABBIN PARK:		
Salaries, Engineering and Clerical	$69.58	$5,715.74
Automobile Purchase	0.00	380.00
Automobile Maintenance	0.00	62.09
Purchases and Settlements	118.00	6,763.10
Perpetual Care Fund Contributions	75.00	175.00
Removal and Reinterment of Bodies	202.20	6,089.95
Removal and Resetting of Monuments	77.72	5,497.74
Miscellaneous Expense	0.00	117.91
Sub Total Removals to Other Cemeteries	$542.50	$24,801.53
Total Quabbin Reservoir Cemeteries	$12,238.55	$96,842.28
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Total	$0.00	$214.78
HIGHWAY AND PUBLIC UTILITY RELOCATION:		
Salaries, Engineering and Clerical	$42,158.79	$137,723.22
Legal and Expert Expense	0.00	49.10
Consultant Expense	0.75	8,450.15
Labor	1,771.20	3,653.21
Furniture and Fixtures	0.00	61.74
Contract No. 21, Construction of about 5.2 miles of the Ware-Belchertown Highway	0.00	129,980.25
Contract No. 40, Removal and Relocation of Transmission and Telephone Lines and Substation of the New England Power Co. and Central Massachusetts Electric Co.	86,744.00	154,790.10
Contract No. 41, Construction of about 9.1 miles of the Belchertown-Pelham Highway in Belchertown and Pelham	52,618.86	106,280.34
Contract No. 43, Construction of about 7.6 miles of Extension of Belchertown-Pelham Highway in Shutesbury and New Salem to New Salem Center	101,092.89	156,388.37
Contract No. 44, Construction of about 4.1 miles of Extension of Belchertown-Pelham Highway in New Salem and Orange	102,542.27	102,542.27
Installed Equipment	394.12	811.57
Temporary Equipment	0.00	149.50
Engineering Instruments	191.46	625.14
Automobile Purchase	0.00	535.00
Automobile Maintenance	1,459.64	3,932.32
Miscellaneous Expense (undistributed)	2,299.82	3,742.94
Printing and Blueprinting	87.31	289.53
Stationery and Office Supplies	6.94	90.34
Total Highway and Public Utility Relocation	$391,368.05	$810,095.09
Total Quabbin Reservoir, Except Main Dam and Dike	$1,376,740.54	$9,340,013.80

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Quabbin Reservoir Main Dam		
General Overhead:		
Administration	$6,032.98	$18,385.19
Engineering	19,521.75	67,509.28
Total General Overhead	$25,554.73	$85,894.47
Engineering:		
Salaries, Engineering and Clerical	$9,253.83	$75,470.77
Consultant Expense	799.49	5,078.51
Labor	2,035.60	5,293.48
Furniture and Fixtures	0.00	64.18
Laboratory Equipment	0.00	444.04
Rental of Equipment	0.00	420.00
Engineering Instruments	55.74	201.56
Rent and Upkeep	291.18	320.08
Automobile Purchase	1,200.00	1,200.00
Automobile Maintenance	405.22	1,204.85
Contracts for Investigations and Surveys	9,518.58	52,229.21
Office Buildings	250.00	250.00
Special Experiments	255.07	1,568.49
Water Supply System	10.00	20.00
Miscellaneous Expense (undistributed)	6,056.89	10,533.43
Printing and Blueprinting	37.11	64.15
Stationery and Office Supplies	0.00	145.05
Postage	0.55	0.55
Total Engineering	$30,169.26	$154,508.35
Permanent Construction — Construction Contracts:		
Completed Contract No. 30	$0.00	$544,610.60
Completed Contract No. 32, Constructing Exploratory Caisson at Main Dam	0.00	48,390.81
Contract No. 36, Constructing Exploratory Caissons at Main Dam	162,162.29	$168,472.48
Total Contracts	$162,162.29	$761,473.89
Permanent Construction — Except Construction Contracts:		
Labor	$1,522.80	$2,491.80
Installed Equipment	0.00	3,253.00
Temporary Equipment	2,969.23	4,213.39
Miscellaneous Expense	1,314.10	2,296.15
Total	$5,806.13	$12,254.34
Total Quabbin Reservoir Main Dam	$223,692.41	$1,014,131.05
Quabbin Reservoir Beaver Brook Dike		
General Overhead:		
Administration	$8,738.78	$20,747.19
Engineering	30,599.65	78,834.42
Total General Overhead	$39,338.43	$99,581.61
Engineering:		
Salaries, Engineering and Clerical	$27,682.55	$67,078.99
Consultant Expense	807.47	4,823.97
Labor	3,043.80	4,925.92
Furniture and Fixtures	0.00	127.22
Laboratory Equipment	0.00	315.73
Rental of Equipment	0.00	921.50
Engineering Instruments	49.00	52.27
Rent and Upkeep	0.00	16.00

	Year ending Nov. 30, 1934	Total to Nov. 30, 1934
Automobile Purchase	$600.00	$600.00
Automobile Maintenance	650.54	1,286.82
Contracts for Investigations and Surveys	5,517.72	23,609.47
Special Experiments	53.60	53.60
Miscellaneous Expense	478.29	4,565.61
Printing and Blueprinting	792.46	1,271.23
Stationery and Office Supplies	9.07	63.19
Advertising	79.34	79.34
Total Engineering	$39,763.84	$109,790.86
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Completed Contract No. 32, Constructing Exploratory Caisson at Dike	$0.00	$114,447.52
Contract No. 36, Constructing a Core Wall to Sound Rock at the Site of the Dike	224,566.10	824,689.36
Total Contracts	$224,566.10	$939,136.88
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$7,873.55	$9,423.95
Temporary Equipment	0.00	305.65
Tools and Equipment	14.70	14.70
Miscellaneous Expense	283.43	1,562.04
Total	$8,171.68	$11,306.34
Total Quabbin Reservoir Beaver Brook Dike	$311,840.05	$1,159,815.69
SOUTHERN SUDBURY EMERGENCY SUPPLY		
GENERAL OVERHEAD:	$0.00	$42,098.25
ENGINEERING:	0.00	44,235.07
REAL ESTATE:	0.00	30,553.18
SOUTHERN SUDBURY DIVERSION DAMAGES	0.00	50,752.66
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS		
Completed Contracts Nos. 6, 7, 11, 13, 15, 16	0.00	375,194.44
Completed Contract No. 5 Cordaville Pipe Line	500.00	83,762.86
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS	0.00	11,937.37
Total Southern Sudbury Emergency Supply	$500.00	$638,533.83
SUMMARY		
Wachusett-Coldbrook Tunnel, Ware Supply	$618,416.54	$12,752,074.29
Special Investigation — Pollution of Ware and Quinapoxet Watersheds	0.00	1,995.99
Coldbrook-Swift Tunnel	882,095.52	4,857,661.99
Quabbin Reservoir Except Main Dam and Dike	1,376,740.54	9,340,013.80
Quabbin Reservoir Main Dam	223,692.41	1,014,131.05
Quabbin Reservoir Beaver Brook Dike	311,840.05	1,159,815.69
Southern Sudbury Emergency Supply	500.00	638,533.83
Unassigned	−9.21	563.42
Grand Total	$3,413,275.85	$29,764,790.06
RECEIPTS FROM RENTS, SALES, ETC.		
Sales	$17,257.71	$133,031.02
Rents	50,309.48	304,301.23
Miscellaneous	2,104.39	5,276.03
Total Receipts	$69,671.58	$442,608.28

Commonwealth of Massachusetts
METR. DISTR. WATER SUPPLY COMMISSION

CANVASS OF BIDS FOR CONTRACT 50

OPENED NOV. 13, 1934

FOR CONSTRUCTING THE EMBANKMENT OF THE DIKE OF THE QUABBIN RESERVOIR IN THE TOWNS OF ENFIELD AND WARE

				The Arthur A. Johnson Corporation, 29-28 Hunter Ave., Long Island City, N.Y. ① *		West Construction Company, 60 State St., Boston, Mass. ②		S.J. Groves & Sons, Co. Wesley Temple Bldg. Minneapolis, Minn. ③		B. Perini & Sons, Inc., Framingham, Mass. ④		The Arundel Corporation Pier 2, Pratt St., Baltimore, Md. ⑤		Rosoff Tunnel Corporation 295 Madison Ave., New York N.Y. ⑥	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1	Clearing and grubbing	Acre	150	240.00	$36,000.00	50.00	$7,500.00	150.00	$22,500.00	180.00	$27,000.00	250.00	$37,500.00	200.00	$30,000.00
2	Earth excavation	Cu.Yd.	50,000	30	15,000	30	15,000	75	37,500	68	34,000	65	32,500	80	40,000
3	Rock excavation for core wall	Cu.Yd.	12,000	2.60	31,200	3.20	38,400	4.00	48,000	3.50	42,000	4.20	50,400	6.00	72,000
4	Rock excavation except for core wall	Cu.Yd.	6,000	2.00	12,000	2.00	12,000	2.00	12,000	3.50	21,000	1.75	10,500	2.30	13,800
5	Consolidated pervious foundation embankment	Cu.Yd.	175,000	35	61,250	50	87,500	50	87,500	65	113,750	40	70,000	1.93	337,750
6	Rolled impervious embankment in core	Cu.Yd.	60,000	45	27,000	60	36,000	75	45,000	79	47,400	50	30,000	1.93	115,800
7	Rolled impervious embankment except in core	Cu.Yd.	85,000	40	34,000	59	50,150	75	63,750	79	67,150	42	35,700	1.93	164,050
8	Embankment by full-hydraulic method	Cu.Yd.	2,100,000	39	819,000	.405	850,500	50	1,050,000	49	1,029,000	.496	1,041,600	47	987,000
9	Miscellaneous embankment	Cu.Yd.	10,000	26	2,600	30	3,000	40	4,000	25	2,500	50	5,000	35	3,500
10	Selected coarse material	Cu.Yd.	100,000	65	65,000	48	48,000	50	50,000	49	49,000	50	50,000	47	47,000
11	Crushed stone or screened gravel	Cu.Yd.	20,000	90	18,000	1.10	22,000	1.75	35,000	2.00	40,000	1.75	35,000	2.50	50,000
12	Light riprap	Cu.Yd.	100,000	1.05	105,000	1.10	110,000	1.25	125,000	1.50	150,000	1.61	161,000	1.80	180,000
13	Heavy riprap	Cu.Yd.	19,000	1.45	27,550	1.75	33,250	2.25	42,750	1.50	28,500	4.00	76,000	2.50	47,500
14	Paving	Cu.Yd.	1,200	7.00	8,400	3.00	3,600	4.00	4,800	6.25	7,500	10.50	12,600	4.00	4,800
15	Soil dressing	Cu.Yd.	40,000	70	28,000	95	38,000	75	30,000	98	39,200	88	35,200	1.20	48,000
16	Seeding and grassing	Acre	30	250.00	7,500	120.00	3,600	175.00	5,250	150.00	4,500	250.00	7,500	55.00	1,650
17	Gravel sub-base for roads	Cu.Yd.	6,000	1.00	6,000	43	2,580	70	4,200	44	2,640	1.40	8,400	1.50	9,000
18	Broken stone base for roads	Cu.Yd.	1,800	4.00	7,200	2.85	5,130	3.25	5,850	5.25	9,450	5.00	9,000	1.25	2,250
19	Broken stone surface for roads	Ton	2,500	4.25	10,625	2.60	6,500	3.75	9,375	2.89	7,225	4.75	11,875	3.50	8,750
20	Bituminous material	Gallon	40,000	20	8,000	16	6,400	15	6,000	14	5,600	20	8,000	15	6,000
21	Cable guard rail	Lin.Ft.	1,500	2.00	3,000	60	900	1.00	1,500	60	900	2.00	3,000	1.75	2,625
22	Boulder guard rail	Lin.Ft.	1,000	1.00	1,000	3.00	3,000	1.00	1,000	75	750	2.00	2,000	45	450
23	Stone walls	Cu.Yd.	1,400	8.50	11,900	3.60	5,040	10.00	14,000	6.00	8,400	14.00	19,600	2.75	3,850
24	Drilling holes in rock and masonry	Lin.Ft.	2,500	60	1,500	1.75	4,375	1.00	2,500	45	1,125	50	1,250	70	1,750
25	Furnishing and placing grout	Cu.Yd.	1,000	9.50	9,500	9.50	9,500	30.00	30,000	7.75	7,750	18.00	18,000	25.00	25,000
26	Preparing rock surface	Sq.Yd.	1,500	60	900	4.85	7,275	1.00	1,500	45	675	88	1,320	1.00	1,500
27	Portland cement	Barrel	10,000	2.85	28,500	2.45	24,500	2.50	25,000	2.62	26,200	4.40	44,000	2.45	24,500
28	Concrete, Class A.	Cu.Yd.	2,500	10.00	25,000	13.25	33,125	10.00	25,000	16.50	41,250	10.00	25,000	6.75	16,875
29	Concrete, Class B.	Cu.Yd.	50	15.00	750	13.25	662.50	20.00	1,000	9.00	450	25.00	1,250	7.75	387.50
30	Reinforcing steel	Pound	5,000	06	300	05	250	10	500	04	200	07	350	04	200
31	Miscellaneous steel and iron	Pound	60,000	10	6,000	15	9,000	08	4,800	09	5,400	15	9,000	10	6,000
32	Miscellaneous bronze, brass and copper	Pound	1,000	60	600	35	350	75	750	50	500	1.05	1,050	35	350
33	Twelve-inch tile pipe	Lin.Ft.	5,000	1.20	6,000	2.40	12,000	1.75	8,750	1.00	5,000	1.14	5,700	1.40	7,000
34	Eighteen-inch tile pipe	Lin.Ft.	700	2.40	1,680	3.50	2,450	2.00	1,400	1.75	1,225	1.75	1,225	2.25	1,575
35	Twenty-four-inch tile pipe	Lin.Ft.	200	4.00	800	6.70	1,340	2.25	450	2.65	530	4.00	800	3.50	700
36	Sampling wells	Lin.Ft.	2,000	1.20	2,400	5.60	11,200	.85	1,700	2.00	4,000	2.80	5,600	1.70	3,400
37	Maintenance of Engineer's office	Month	45	100.00	4,500	125.00	5,625	25.00	1,125	25.00	1,125	262.00	11,790	10.00	450
38	Removal of brook diversion and caisson equipment	Lump Sum		1,000.00	1,000	950.00	950	2,000.00	2,000	2,000.00	2,000	8,000.00	8,000	1,000.00	1,000
39	Cleaning up	Lump Sum		12,000.00	12,000	1,250.00	1,250	5,000.00	5,000	2,000.00	2,000	3,000.00	3,000	1,500.00	1,500
		Totals			$1,446,655.00		$1,511,902.50		$1,816,450.00		$1,836,895.00		$1,889,710.00		$2,267,962.50

* Contract awarded Nov. 26, 1934.
Contract executed Dec. 3, 1934.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED BETWEEN NOV. 30, 1933 AND NOV. 30, 1934

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
40	Removal & Relocation of Transmission, Telephone Lines & Sub-Sta.	New Salem, Belchertown, Enfield and Ware.	Swift	New Eng. Power Co., & Central Mass. Electric Co.	Date of Agreement = June 20, 1933.			Actual Cost Damages	$ 104,790.10 50,000.00	Feb. 15, 1934
45	Exploration by Shovel Cuts of Borrow Areas for Dam & Dike.	Belchertown, Enfield and Ware.	Swift	B. Perini & Sons, Inc.	Feb 6, 1934	6	Feb. 6, 1934	$ 6,200.00	9,425.09	Oct. 22, 1934

STATUS OF CONTRACTS IN FORCE ON NOV. 30, 1934

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	PAYMENTS TO DATE
20	Coldbrook-Swift Tunnel.	Barre, Hardwick and Greenwich	Swift	Wenzel & Henoch, Construction Co.	Mar. 27, 1931	13	April 10, 1931	$ 4,978,031.80	$ 4,444,062.05
23	Making Borings.	Belchertown, Ware, Enfield, Greenwich & Hardwick.	Swift	Sprague & Henwood Inc.	Nov. 5, 1929	6	Nov. 5, 1929	10,950.00	46,541.31
33	Purchase of Power at Shaft 1.	West Boylston	Ware	New England Power Co.	Date of Agreement = Aug. 6, 1931			Agreed Rates	1,767.63
35	Purchase of Power at Dam Site.	Enfield	Swift	New England Power Co.	Date of Agreement = June 2, 1932			Agreed Rates	10,631.40
36	Core Wall to Sound Bed Rock at Dike Site.	Enfield & Ware	Swift	West Construction Co.	Dec. 9, 1932	25	Dec. 28, 1932	999,265.00	993,161.84
39	Construction of Trunk Sewer.	Rutland & Holden	Ware	James J. Coughlan & Sons, Inc.	July 7, 1933	21	July 11, 1933	184,327.50	192,523.91
41	Construction of Portion of Belchertown-Pelham Highway.	Belchertown & Pelham	Swift	Carlo Bianchi Co., Inc.	July 18, 1933	14	July 19, 1933	222,335.50	** 219,160.09
42	Use of Worcester Sewerage System and Treatment Works % Rutland-Holden Sewer.	Worcester	Ware	City of Worcester	Date of Agreement May 1, 1933		Lump Sum = Annual Charge =	325,000.00 *	325,000.00 None
43	Construction of Extension of Belchertown Pelham Highway to New Salem Center.	Shutesbury & New Salem	Swift	V. Barletta Co.	Aug. 11, 1933	7	Aug. 22, 1933	300,397.50	** 239,313.95
44	Construction of Extension of Belchertown Pelham Highway North of New Salem Center.	New Salem & Orange	Swift	John Iafolla Construction Co.	Nov 10. 1933	9	Nov. 14, 1933	179,480.50	** 155,421.45
46	Connection with Rutland-Holden Sewer, & Disposal of Sewage from the U.S. Veteran's Hospital.	Rutland (Note: Payments under Contract 46, are to be received by the M.D.W.S.C.)	Ware	U.S. Veteran's Administration	Date of Agreement = Nov. 7, 1934		Lump Sum = Annual Charge =	37,000.00 *	None None
50	Dike Embankment-Quabbin Reservoir.	Enfield & Ware	Swift	The Arthur A. Johnson Corporation.	Nov. 13, 1934	6	Nov. 26, 1934	1,446,655.00	None

* Proportion of Annual Maintenance Cost.

** Of these amounts the State Dept. of Public Works has paid $112,879.75 on Cont. 41, $82,925.58 on Cont. 43 and $52,879.18 on Cont. 44 covering the surfacing, guard rail and traffic signal duct items.

The above contracts were all awarded to the lowest bidder except Contract 43 which was awarded to the 2nd lowest bidder.

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TAKINGS OF REAL ESTATE (AND WATER RIGHTS)

TAKING FOR	TAKING NO.	TOWN	COUNTY	DATE OF TAKING	PLAN NO.	TITLE VESTED IN COMMONWEALTH FEE (Acres)	TITLE VESTED IN COMMONWEALTH EASEMENT (Acres)
Southern Sudbury Emergency Supply.	1 to 9 incl.	Details previously reported. See 1930 Annual Report.			C-1 to C-15 incl.	258.81 (Also Water Rights)	29.02
Wachusett-Coldbrook Tunnel section of Quabbin Aqueduct.	1 to 4 incl.	Details previously reported. See 1930 Annual Report.			T-1 to T-13 incl.	570.22	20.37
Coldbrook-Swift Tunnel section of Quabbin Aqueduct.	1 to 3 incl.	Details previously reported. See 1931 Annual Report. *(391.42 acres of this total are within the Quabbin Reservoir Area)			T-14 to T-27 incl.	*544.81	4.06
Quabbin Reservoir.	1 to 12 incl.	Details previously reported. See 1931, 1932 and 1933 Annual Reports.			S-1 to S-27 incl.	605.41	19.85
" "	13	New Salem	Franklin	May 22, 1934	S-28	31.60	
						637.01	19.85
Ware River Water Shed.	1 to 2 incl.	Details previously reported. See 1932 and 1933 Annual Reports.			W-1 and A-1 to A-14 incl.	0.25 (Also Water Rights)	22.94

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE QUABBIN RESERVOIR

(TITLE VESTED IN COMMONWEALTH)

TOWNS	TOTAL – Nov. 30, 1933. 1933 ANNUAL REPORT (ACRES)	TOTAL – Nov. 30, 1933. REVISED - SEE NOTE (ACRES)*	TOTAL FOR YEAR ENDING Nov. 30, 1934 (ACRES)	TOTAL Nov. 30, 1934 (ACRES)	REMARKS
BELCHERTOWN	2,609	2,613	190	2,803	
DANA	7,886	7,895	341	8,236	
ENFIELD	7,695	7,696	135	7,831	* Revisions have been made using acreages obtained from surveys wherever available, otherwise from deeds, property blanks, etc.
GREENWICH	9,923	9,923	552	10,475	
HARDWICK	2,544	2,551	424	2,975	
NEW SALEM	6,665	6,686	1,297	7,983	
ORANGE	—	—	1	1	
PELHAM	4,209	4,201	366	4,567	
PETERSHAM	686	686	33	719	
PRESCOTT	9,747	9,749	478	10,227	
SHUTESBURY	1,662	1,663	962	2,625	
WARE	645	643	79	722	
WENDELL	36	36	—	36	
TOTALS	54,307	54,342	4,858	59,200	

REPORT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

To the Honorable the Senate and House of Representatives of the Commonwealth of Massachusetts in General Court assembled.

The Metropolitan District Water Supply Commission, established under the provisions of Chapter 375 of the Acts of 1926, respectfully presents for the year ending November 30, 1935, its

TENTH ANNUAL REPORT

I. Organization and Administration

Eugene C. Hultman, of Boston, succeeded Davis B. Keniston as Chairman of the Commission on December 27, 1934. Charles M. Davenport and Thomas D. Lavelle, both of Boston, continued during the year as Associate Commissioners. R. Nelson Molt continued as Secretary.

The clerical force of the Commission's office at Boston remained substantially the same throughout the year. Three special agents under the direction of the Commission continued to care for the property acquired by the Commission in the Swift River and Ware River areas. Real estate purchasing agents and conveyancers and other experts were employed as needed. The engineering and clerical force of the engineering department averaged 146 employees during the year. The maximum number employed at any one time by contractors on the various construction projects during the year was 698 persons. From time to time temporary local laborers were employed by the Commission for the removal of bodies and in miscellaneous work of maintenance.

The Commission continued, through duly appointed agents, the direction of the town government of the Town of Prescott, as provided by Chapter 340 of the Acts of 1928. A financial statement for the town is included in the Commission's report to the Commissioner of Corporations and Taxation.

II. Engineering Department

Frank E. Winsor continued as Chief Engineer, Karl R. Kennison as Assistant Chief Engineer, and Walton H. Sears as Mechanical Engineer.

The field divisions continued as follows: Quabbin Reservoir Division at Enfield, Mass., in charge of N. Leroy Hammond; Coldbrook-Swift Tunnel Division of Quabbin Reservoir until its discontinuance October 31, in charge of Richard R. Bradbury; Dam and Aqueduct Division in charge of William W. Peabody.

Charles T. Main, Inc., of Boston, was employed from time to time as a general consultant on mill and water power damages and also on the design of the dam and dike of Quabbin Reservoir. Dr. Charles P. Berkey of Columbia University continued as consulting geologist. Other consultants were employed from time to time as needed.

The Commission regrets to report the death on August 10 of Mr. X. H. Goodnough. By the death of Mr. Goodnough the Commission lost the services of one who was particularly well fitted to advise them on this project. Mr. Goodnough devoted a lifetime to the service of the state. He was born in Brookline, Massachusetts, in 1861. Shortly after graduating from Harvard University and obtaining a variety of experience in engineering work, he was employed by the State Board of Health in various capacities. He was Chief Engineer of the Board, later the State Board of Health, for 35 years previous to his retirement in 1930. Under his direction the department developed into one of the most important agencies of the state for the protection of the public health and the development and conservation of its resources. He acted as Chief Engineer of the Joint Board to investigate water supply needs and resources of the State, which investigation led to the present extension of the water supply sources of the Metropolitan District to the Ware and Swift rivers.

III. Offices

The office of the Commission and of the Chief Engineer continued on the ninth floor of the Metropolitan District Commission Building at 20 Somerset

Street, Boston. The only change in the offices of the Commission was the discontinuance of the Coldbrook-Swift Tunnel Division of Quabbin Aqueduct on October 31. The laboratories for water analysis and soil testing were continued at Enfield.

IV. Real Estate and Water Rights

The Commission, for reservoir purposes, has acquired a total of approximately 63,504 acres of land in the Swift River watershed, and for sanitary protection and construction purposes in the Ware River watershed a total of about 6,195 acres.

The exceptions taken to the Supreme Judicial Court by the Commission to the report in the petition of Maher and Duggan brought by Thomas F. Maher and John J. Duggan under the provisions of Section 5 of Chapter 321 of the Acts of 1927 which report awarded $221,000 for land owned by the petitioners in Greenwich and necessary for reservoir purposes was heard and the Supreme Judicial Court sustained the exceptions and the Commission has petitioned for a new board of referees to rehear the petition.

Upon petitions of the selectmen of the towns of Ware and Enfield, the so-called river road from the Ware-Belchertown highway south of the main dam, northerly through the valley to its intersection with the highway leading from Belchertown to the village of Enfield was discontinued as a public way by the County Commissioners of Hampshire County on August 13. This, together with the previous abandonment of the Athol Branch of the Boston and Albany Railroad, cleared the way for the construction of the main dam. The last passenger train on the Athol Branch of the Boston and Albany Railroad ran on June 1.

As a result of the opinion of the Attorney General given to His Excellency the Governor and Honorable Council, the Commission was required in August to submit to the Honorable Governor and Council for approval settlement of all claims and to secure the approval of all new projects prior to their acceptance by the Commission.

V. Ware River Supply

Agreements were completed with the United States Veterans Administration and the State Department of Public Health covering the connections of the sewers of their hospitals in Rutland and the use of the Rutland-Holden trunk sewer for the diversion of the sewage to the Worcester sewerage system. This trunk sewer was operated throughout the year.

The temporary chlorinating plant in the upper watershed of the Ware River was operated on November 30.

Water was diverted from the Ware River three days in January, seven days in February and two days in March.

VI. Swift River Supply

Real estate and topographic surveys were continued during the year. Some reforestation of the areas of Quabbin Reservoir above the flow line was instituted.

The Wenzel and Henoch Construction Company completed on October 1 the work under Contract 20 for the construction of the Coldbrook-Swift section of the Quabbin Aqueduct, thus completing the 24.6 miles of aqueduct between the west end of the Wachusett Reservoir and Quabbin Reservoir in the Swift River Valley.

The remainder of the construction of a highway west of the reservoir site about 21 miles long from Belchertown to a point on the road between North Dana and Orange just north of the Orange town line was completed and taken over by the Department of Public Works as a state highway. This highway has been named "Daniel Shays Highway" commemorating a local historic event of national importance, namely, Daniel Shays's Rebellion in 1787, Daniel Shays himself owning a farm in what is now the town of Prescott and leading a group of men, drilled on Pelham Common, on the arsenal at Springfield, where they were dispersed by State Militia and fled through Amherst and Prescott to Petersham, where they were finally captured.

Contract 38 was awarded on May 9 to C. J. Maney Company, Inc., Boston, and B. Perini & Sons, Inc., Framingham, operating as The Two Companies,

Inc., for constructing a core wall to sound rock at the site of the main dam of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware. Work has been in progress under this contract, the open trench across the valley, about 25 feet below the level of the Swift River, being completed and the caisson core wall substantially completed. There are in all 40 caissons across the valley. Thirty-five of these have been sunk to bedrock and sealed. Of the remaining 5, 2 are in the process of sealing and 3 are practically down to bedrock.

Contract 49 was awarded on October 1 to Cenedella & Company, Milford, Mass., for excavating diversion channels at the site of Quabbin Reservoir, one at the lower intake to Quabbin Aqueduct, one at the outlet from Shaft 11A, and one across the divide between the East and Middle Branches of Quabbin Reservoir. Work has been in progress under this contract.

The Arthur A. Johnson Corporation continued under Contract 50 for constructing the embankment of the dike of Quabbin Reservoir. The foundation embankments have been completed along both upstream and downstream toes and the work is in progress on the hydraulic sluicing of the main embankment.

VII. General

The engineering force continued its studies of the development of hydroelectric power at various points on the work. No electric power development is practicable until the completion of Quabbin Reservoir provides the necessary storage of water.

Plans are being made for the general reforestation of areas purchased by the Commission except those located below the flow line of Quabbin Reservoir. An experimental nursery was established in the Town of Greenwich and planting of seedling conifers was commenced in cleared areas on the "Prescott Peninsula."

Permission was granted for the construction on land of the Commonwealth in Belchertown of a camp for the Civilian Conservation Corps. This camp is located just south of the Ware-Belchertown Highway and about one-half mile west of the Swift River. Permission was also granted for the construction by the Emergency Relief Administration of miscellaneous water holes to be used for fire protection.

VIII. Cemeteries

The Commission has continued the assignment of lots in the new Quabbin Park Cemetery and 553 bodies were removed from the Quabbin Reservoir area during the year, of which 514 have been interred in Quabbin Park Cemetery. To date a total of 2,465 bodies has been removed from the Quabbin Reservoir area, and there have been 71 original burials in this cemetery.

IX. Financial

The Commission appends hereto a statement of its expenditures and disbursements for the fiscal year, and from the date of its appointment.

X. Other Reports

The report of the Chief Engineer is herewith presented. It includes a report on the geology of the region in which the Commission's operations have been conducted.

XI. Recommendation

As it is doubtful that the provisions of Section 9 of Chapter 321 of the Acts of 1927 are broad enough to authorize the Treasurer and Receiver General to receive and invest funds for the perpetual care of lots in Quabbin Park Cemetery established by the Commission, it is recommended that a special resolve which the Commission has filed be passed substantially in the form submitted herewith.

Respectfully submitted,

E. C. HULTMAN, *Chairman.*
CHARLES M. DAVENPORT, *Associate Commissioner.*
THOMAS D. LAVELLE, *Associate Commissioner.*

20 Somerset Street, Boston, Mass.
January 15, 1936.

RESOLVE TO AUTHORIZE THE TREASURER AND RECEIVER-GENERAL TO RECEIVE AND INVEST FUNDS FOR THE PERPETUAL CARE OF LOTS IN QUABBIN PARK CEMETERY, WARE, MASSACHUSETTS.

Resolved, that the Treasurer and Receiver-General of the Commonwealth of Massachusetts be and hereby is authorized to receive, hold and invest such funds as may be paid to him from time to time by the Metropolitan District Water Supply Commission or by others, for the perpetual care of cemetery lots originally or relocated in Quabbin Park Cemetery, as a special fund entitled "Perpetual Care of Lots in Quabbin Park Cemetery, Ware, Massachusetts."

Resolved, that the Treasurer and Receiver-General be and hereby is authorized upon the completion or transfer of Quabbin Park Cemetery to pay such fund together with any accumulations thereon to such trustees, persons, or municipality, or to the Town of Ware, or to its officials charged with the care of cemeteries, to whom Quabbin Park Cemetery upon its completion shall be transferred by the Metropolitan District Water Supply Commission.

REPORT OF THE CHIEF ENGINEER

To the Metropolitan District Water Supply Commission.

GENTLEMEN:—The following is a report of the engineering department for the year ending November 30, 1935.

ORGANIZATION

The engineering organization has been decreased about 14 per cent in number during the year.

Karl R. Kennison, Assistant Chief Engineer, continued in charge of all studies in connection with the general plan of the work and the design of structures, preparation of contract specifications, contract and working drawings.

Charles L. Coburn and Stanley M. Dore, Assistant Designing Engineers until November 1 and since then Associate Civil Engineers, continued their general supervision of the detailed work of the office; and Walton H. Sears, Mechanical Engineer, continued in charge of the collection of data in connection with mill and water power damages. They have assisted in the preparation of contract specifications.

Three division engineers continued in charge of field divisions as follows: William W. Peabody, Dam and Aqueduct Division until November 4 and thereafter the Quabbin Aqueduct Division; Richard R. Bradbury, Coldbrook-Swift Tunnel Division until its discontinuance October 31; N. LeRoy Hammond, Quabbin Reservoir Division.

X. Henry Goodnough, Inc., continued as consulting engineer until Mr. Goodnough's death on August 10. Charles T. Main, consulting engineer of Boston, Dr. Charles P. Berkey, geologist of Columbia University and other experts were employed from time to time.

The assignment of employees under the direction of the Chief Engineer at the end of the year and of the preceding year was as follows:

	Nov. 30, 1934	Nov. 30 1935
Headquarters Office, Designing Division	39	39
Main Dam Core Wall Office	—	27
West Ware Office, Dam and Aqueduct Division	19	—
Coldbrook Office, Quabbin Aqueduct Division	—	14
Hardwick Office, Coldbrook-Swift Tunnel Division	40	—
Enfield Office, Quabbin Reservoir Division	61	57
Total Engineering Force	159	137

The maximum force during the year was 159, during the four weeks ending December 29, 1934. The minimum force was 137, during the three weeks ending November 30. The average force for the year was 146.

OFFICES

The office of the Chief Engineer and Designing Division was continued in the Metropolitan District Commission Building at 20 Somerset Street, Boston. The office of the Dam and Aqueduct Division was continued at the site of the main dam of Quabbin Reservoir in West Ware until November 4, when the work of sinking the caissons for the main dam core wall was nearly completed and this division was superseded by the Quabbin Aqueduct Division. The office of the Coldbrook-Swift Tunnel Division was continued in the brick building formerly used as a school at Hardwick Center until October 31, when this division was discontinued. On November 4 the Quabbin Aqueduct Division was established with an office in the Ware River intake building in Coldbrook, and with a branch office at Shaft 12 of Quabbin Aqueduct in a building formerly used as a field office during the construction of the Coldbrook-Swift Tunnel. The office at the site of the main dam continued to be occupied by the force engaged upon the completion of the caisson core wall, this force after November 4 being in charge of Senior Civil Engineer Frederick W. Gow. The office of the Quabbin Reservoir Division was continued in the property of the Commonwealth formerly known as the Frances W. Chandler house on Quabbin Road, and the laboratories for water analysis and for soil testing were continued in the property of the Commonwealth formerly known as the Barlow house in Enfield.

Headquarters Office

Summary of the Year's Work

Real Estate.—Reports and recommendations with respect to the purchase of real estate in the Quabbin Reservoir area were submitted to the Commission during the year covering 3,966 acres, making a total reported on to date of 79,199 acres.

Progress of Real Estate purchases for Quabbin Reservoir

	Total Area Negotiated Including Owners' Offers to Sell to Commonwealth (Acres)	Title Vested in Commonwealth (Acres)
Total for year ending Nov. 30, 1935	3,966	4,304*
Total to Nov. 30, 1934	75,233	59,200
Total to Nov. 30, 1935	79,199**	63,504

Options outstanding Nov. 30, 1935, include 1,509 acres.
* Includes some offered in previous years.
** Includes 6,336 acres not required.

Reports and recommendations were also made with respect to the purchase of real estate for sanitary protection in the Ware River watershed above the intake works at Coldbrook.

Progress of Real Estate Purchases for Ware River Watershed Protection

	Title Vested in Commonwealth (Acres)
Total for year ending Nov. 30, 1935	663
Total to Nov. 30, 1934	5,532
Total to Nov. 30, 1935	6,195

Options outstanding Nov. 30, 1935, include 659 acres.

The only taking during the year was of the waters of Beaver Brook above the dike of Quabbin Reservoir, as shown in the appended table.

Diversion, Land and Business Damage Cases.—Data were prepared for the use of the attorneys in water diversion, land and business damage cases before the courts. Conferences were held and data collected jointly with representatives of manufacturers who have filed claims for diversion damages.

Contracts and Specifications.—Plans and specifications were completed for Contract 38, for constructing a core wall to sound rock at the site of the main dam of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware. The contract was executed May 15.

Contract 48, an agreement with the State Department of Public Health, as to compensation for the right to discharge the sewage of the Rutland State Sanatorium into the Rutland-Holden sewer constructed under Contract 39, became effective when the sewer connection was completed November 7, 1934.

Plans and specifications were prepared for Contract 49, for excavating diversion channels in the towns of Dana, Hardwick and Greenwich, one completing the connection from Quabbin Lake on the East Branch of the Swift River to the lower intake of Quabbin Aqueduct at Shaft 12, one completing the outlet channel from Shaft 11A, and one across the divide between the East and Middle branches. The contract was executed October 2.

Contract 50, for constructing the embankment of the dike of Quabbin Reservoir in the towns of Enfield and Ware, was executed December 5.

Working drawings for Contracts 20, 36, 38 and 50 were prepared and issued.

Plans and specifications were completed for constructing the superstructure of the head house at Shaft 9 of Quabbin Aqueduct and the service building and the superstructure of the head house at Shaft 12 in the towns of Barre and Greenwich.

Work was in progress on the preparation of plans and specifications for constructing a baffle across the East Branch of the Swift River at the outlet of Walker's Mill Pond in the Town of Greenwich.

Inspection and Tests.—E. L. Conwell and Company continued the testing of cement until the latter part of March, after which time the testing was done by The Haller Testing Laboratories, Inc., of Plainfield, N. J. The Worcester Polytechnic Laboratory continued the testing of steel reinforcement bars and concrete cylinders. Steel reinforcement bars furnished for the main dam core

wall under Contract 38 were tested and inspected by William R. Conard of Burlington, N. J. The inspection of miscellaneous iron furnished under Contract 20 was made by the engineering force.

Hydrographic Data.—The gaging station on the Ware River at Coldbrook was continued in cooperation with the United States Geological Survey.

The gaging station on the Chicopee River at the United Electric Light Company plant at Bircham Bend was continued in cooperation with that company and the United States Geological Survey.

The gaging station on the Swift River at Bondsville was continued in cooperation with the Otis Company.

The gaging station on the Swift River above the intake to the stream control tunnel at the main dam site was continued.

Cooperation with the United States Geological Survey in the operation and maintenance of the gaging station on the Connecticut River at Thompsonville, Connecticut, was continued.

In connection with the examination of the waters of the Ware, Swift and Chicopee rivers, observations of flow were continued from time to time and additional temporary gaging stations established as required and data for the use of consultants and experts were prepared.

Ware River Diversion

Ware River water was diverted into Wachusett Reservoir January 24, 25 and 31, February 16 to 19 inclusive, 21, 26 and 27, and March 4 and 5. No water was diverted between May 31 and December 1. At other times, the daily flow in the river was frequently sufficient to permit diversion, but except as above stated no diversion was made because of the present inadequacy of storage capacity in the reservoirs of the District. The quantity of water diverted during the year was 127,900,000 gallons. The steel bulkhead and gates, about 2,200 feet west of Shaft 8, prevent any flow of the Ware River westerly during diversion. This bulkhead will be removed upon the completion of Quabbin Reservoir.

Sewage Diversion from Ware River Watershed

The Rutland-Holden sewer continued in operation. The fiscal year of the City of Worcester has been changed from the 12 months ending November 30 to agree with the calendar year, so that the current fiscal year includes 13 months ending December 31, 1935. During this period of 13 months, 31,028,200 gallons of sewage were received from the U. S. Veterans Hospital and 52,235,600 gallons discharged into the sewerage system of the City of Worcester.

Design of Structures

Shaft 1. Wachusett Outlet.—Studies were resumed of the requirements for the installation of gates to control the discharge from Quabbin Aqueduct into Wachusett Reservoir.

Power Development at Shaft 1.—Studies were resumed of the development of hydroelectric power and of the size and characteristics of the unit to generate power from the water discharged from Quabbin Aqueduct into Wachusett Reservoir.

Shaft 9.—Designs were continued for the superstructure of the head house at the top of Shaft 9 and for the requirements of an electric hoist to handle men and equipment in and out of the aqueduct at this point.

East Branch Baffle.—Studies were continued and designs made for a baffle across the East Branch of the Swift River near the outlet of Walker's Mill Pond. These designs include a concrete conduit through the base of the earth fill to carry the flow of the East Branch in its normal channel as long as desired. After this conduit is closed the entire flow of the East Branch will be diverted northerly so that the flow from the Ware discharged at Shaft 11A and from the East Branch will have the important benefit of longer storage in the main body of Quabbin Reservoir.

Shaft 11A.—Designs were made for one-way shutters to be installed at the top of Shaft 11A, to permit the discharge into the reservoir of water diverted from the Ware River and to prevent the drawing of water from the reservoir into the tunnel.

Shaft 12. Swift River Intake.—Studies were continued and designs made for the head house and the service building at the intake. Designs were continued of stop shutters required for unwatering the tunnel and of one-way shutters to permit the drawing of water from the reservoir into the tunnel and to prevent discharge into the reservoir of water diverted from the Ware River. Studies and designs were made of a water supply for the proposed buildings at Shaft 12, including a 15,000 gallon underground concrete tank 16 feet in diameter and 10 feet deep, about 45 feet above the floor of the service building. This tank is fed from a spring about 40 feet higher than the tank. Studies were made of the requirements for power to operate the shaft hoist and to furnish lights.

Shallow Flowage.—Studies were continued of the possibility of eliminating certain areas of fluctuating shallow flowage in the margins of Quabbin Reservoir by the construction of low dams to maintain the water level in such areas, when the main reservoir is drawn down.

Pumping Ground Water.—Studies were continued of the permeability of foundation materials at both the dike site and the main dam site, particularly the latter. Pumpage was continued at the rate of about 5,000 gallons per minute at the beginning of the year but this figure was gradually reduced during December and January to about 3,500. The ground water surface was lowered a maximum of about 85 feet below the original water level in the river to a point about 30 feet above the bottom of the rock gorge. This proved to be the practicable limit at the site and corresponded to a pumping rate of slightly less than 3,500 gallons per minute. This rate was maintained almost constantly during the remainder of the year and held the ground water near the condition existing at the end of January. The average permeability of materials below the ground water surface was estimated to be about 35 million gallons per acre per day under unit slope at 50° F. This corresponds to an average permeability of about 28 million gallons found at the dike site.

Caisson Core Walls.—Miscellaneous studies were continued in connection with the sinking of caissons for the core walls at the main dam and dike. The frictional resistance to sinking encountered at these sites was estimated to vary to a maximum of 500 pounds per square foot of vertical face below the surface from which the caisson is sunk. The caissons are designed with a slight taper of 1-32 of an inch in 1 foot on each of the two 45-foot sides, the two 9-foot ends being without any taper.

Main Dam and Dike Embankments.—Studies were continued and designs made for the embankment of the main dam. Studies were continued of methods of utilizing existing materials in the construction of the embankment. Studies were continued of observation wells to enable the future inspection, at all levels, of the interior of the impervious core of the hydraulic fill embankments. Three such wells are planned, two at the main dam and one at the dike, founded on the top of the caisson core wall and each being an extension of one of the wells in the core wall. At the bottom of each well, at an elevation near the original valley floor, piezometer connections will make it possible to observe the water pressure or head acting on both upstream and downstream sides of the core wall. The wells will be steel cylinders, 36 inches in diameter with frequent ports which can be opened for observing and taking samples of the core material to determine its degree and rate of compaction.

Office Buildings and Boathouse.—Studies were continued of the locations and requirements of permanent office and maintenance buildings including boathouse and hangar to take care of future reservoir inspection service under the condition of fluctuating reservoir level.

Main Dam Spillway.—Studies and designs were continued for the spillway and discharge channel east of the main dam site.

Power Development at Main Dam.—Studies were continued of the requirements of hydroelectric power development at the outlet works downstream from the stream control tunnel at the main dam.

Roads.—Studies were continued of substitute highways around Quabbin Reservoir and of locations for access roads to the main dam.

Aerial Map.—An aerial mosaic map of the site of Quabbin Reservoir was made, scale 1 inch = 1,100 feet.

Quinapoxet River Diversion.—Studies were continued relative to diverting into the aqueduct at Shaft 2 the waters of the Quinapoxet River for storage in Quabbin Reservoir.

Photographic Records.—The taking of moving pictures from time to time to illustrate the progress of the work was continued.

Tunnel Inspection.—The final inspection of the Coldbrook-Swift tunnel was made August 9 upon the practical completion of the construction work and studies were made of the best type of floating equipment for use in future inspections. A party of seven entered the lower intake at Shaft 12 with two canoes which were lowered through the shaft. The party then inspected the entire length of the tunnel section, passed through the doors of the steel bulkhead and inspected the Wachusett-Coldbrook section as far as Shaft 8 beneath the Ware River intake works and returned through the bulkhead leaving by way of Shaft 9. It was demonstrated that floating equipment for tunnel inspection should be of the lightest possible construction. The two canoes which were used proved very satisfactory. Such equipment must be light in order to have a minimum draft and be moved along easily when the party is walking, as traveling in the canoes was found to have no advantage over walking except where the water was deeper than about 0.8 foot over the tunnel invert. It was not practicable to travel in the canoes for more than 3½ miles of the total 13¾ miles. The tunnel was clean and in excellent condition.

Diversion of Industrial Wastes.—Studies were made of methods of diversion of objectionable wastes into the Rutland-Holden sewer constructed under Contract 39.

Quabbin Aqueduct Division

The Dam and Aqueduct Division until November 4, and thereafter the Quabbin Aqueduct Division, continued in charge of all work in connection with improvements on the Ware River watershed, of the construction and maintenance of the Rutland-Holden sewer, of the maintenance and operation of the Ware River intake works at Coldbrook and the Wachusett outlet works at West Boylston, and of miscellaneous surveys and studies in the Quabbin Reservoir area. The construction work at the main dam site is included in the following description of the work of the Quabbin Aqueduct Division.

Office Work

Semi-monthly estimates for Contract 38, one estimate for Contract 49 and the final estimate for Contract 39 were prepared. Additional real estate plans were prepared of miscellaneous property in the Ware River watershed, final tracings being made of about 800 acres. Record plans were prepared of the Rutland-Holden sewer constructed under Contract 39. Final plans were made of the area along the tunnel line and along the watershed divide. This divide is shown on a set of index plans, scale 1 inch = 1,000 feet. Topographic maps were made of the area in the vicinity of the Jefferson Mfg. Company, Holden. Daily rainfall and temperature records and continuous records of the flow of the Ware River were kept at the intake building and daily rainfall records were kept at West Rutland. Studies were continued of materials, comparative costs and methods of construction of the main dam and dike.

Field Work

Topographic surveys were made in the vicinity of the Jefferson Mfg. Company, Holden, covering about 120 acres, at the site of possible borrow areas northeast of the main dam covering about 550 acres, and along the line of the Ware River watershed divide. The survey of this divide was completed, the total length being 75.3 miles including 18.7 miles adjacent to the Wachusett watershed, which had been previously surveyed by the Metropolitan District Commission. A sanitary survey of the operation of the Jefferson Mfg. Company was made during the week ending August 3. Lines and grades were given for for construction under Contracts 38 and 49. Additional stone bounds were set defining property acquired by the Commission in the Ware River drainage area. The triangulation system in the Ware River drainage area was extended and tied to other systems of the United States Coast and Geodetic Survey and of the State Commission on Waterways and Public Lands.

Monthly inspections and reports were made of conditions found at all shaft heads along the Quabbin Aqueduct.

The State Department of Public Health continued its cooperation with this division in the analysis of samples of water and sewage effluents. The chlorinator station on Mill Brook below the Central New England Sanatorium was maintained.

In connection with studies of the method of construction of the main dam and dike, surveys of topsoil and of glacial overburden were continued in the vicinity of both structures.

Operation of Ware River Intake Works

Operation of the Ware River intake works was continued. Water was diverted into the tunnel from time to time in January, February and March. The tunnel was entered for inspection through Shaft 8 on April 8, July 30 and November 5. The one-way drain valves through the bulkhead were opened July 30. The steel bulkhead 2,200 feet west of Shaft 8 continued in excellent condition. The concrete tunnel lining east of the bulkhead and adjacent to the construction operations under Contract 20 was found to be clean and in excellent condition.

Operation of Rutland-Holden Sewer

Operation of the Rutland-Holden sewer was continued. The meter stations at the Rutland State Sanatorium, at the U. S. Veterans Hospital in Rutland, and at the Holden-Worcester boundary line were inspected regularly and wiers and piezometer connections cleaned and records of flow maintained.

Miscellaneous Construction

Between December 15 and May 27, the interval between completion of work on exploratory caissons numbered 7 and 9 at the main dam under Contract 36 and the beginning of work of sinking the remaining caissons to complete the core wall under Contract 38, pumping operations were continued by the Commission's force. The pumping plant was as follows: in caisson 7, eight pumps, each with a capacity of 800 gallons per minute; in caisson 9, three pumps of 800 and one of 300 gallons per minute capacity; and in caisson 20, one of 300 gallons per minute capacity, all these ratings being at 90-foot head. The rate of pumpage decreased from 4,480 gallons per minute on December 15 to 3,490 gallons per minute on May 15.

A small labor force was employed throughout the year on miscellaneous work in caring for the grounds at the Ware River intake, Wachusett outlet and Shaft 4 head house, setting stone bounds, filling cellar holes, grading and cleaning up at the sites of buildings removed from the Ware River watershed and other miscellaneous work. The average number of men so employed on force account was 8, the maximum 20 and the minimum 3.

Progress of Contracts

Contract 35.—Contract 35, with the New England Power Company for the purchase of electricity for experimental work at the main dam site, was continued to completion. Under this contract power was purchased for use in experimental pumping from the exploratory caissons.

During the year a total of 555,000 kilowatt hours was furnished, making the total during the life of the contract 1,159,535 kilowatt hours. The cost of electricity furnished during the year was $8,382.98, making the total cost from June 2, 1932, to June 1, 1935, $19,367.18.

Contract 38.—Bids were opened May 7, for constructing a core wall to sound rock at the site of the main dam of Quabbin Reservoir in the towns of Belchertown, Enfield and Ware. Nine bids were received, ranging from $1,330,765.00 to $1,818,200.00. The contract was executed May 15, with C. J. Maney Company, Inc., Boston, and B. Perini & Sons, Inc., Framingham, the low bidders, who assigned the contract to, and are now operating under the name of The Two Companies, Inc.

The work consists mainly of excavating an open trench across the valley about 2,700 feet long and about 30 feet deep, sinking a row of 37 concrete caissons

(three other caissons were previously sunk for explorations under earlier contracts), from the bottom of this trench to sound rock, refilling both caissons and trench with impervious materials, and constructing consolidated pervious embankments both upstream and downstream to form the toes of the future main dam embankments in preparation for the construction of the latter by hydraulic sluicing.

Excavating of the open trench was started May 17. The removal of the track of the Athol Branch of the Boston and Albany Railroad crossing the site was completed July 31, and the excavation of open trench practically completed, August 20. The highway crossing the site of the dam was discontinued as a public way, August 13. The open-cut trench was extended up the hillsides to the elevation of the top of the dam. Stripping of the site was practically completed. Suitable impervious materials from these operations, together with impervious soil from borrow areas north of the site, were stored for later use in refilling the open trench. Silt and other unsuitable materials from the stripping operations were wasted in the abandoned river bed both upstream and downstream from the site and in other spoil areas. Suitable pervious materials from the excavations were placed in the required embankments. The upstream and downstream cofferdams, forming the toes of the future embankment, were built and fills between these cofferdams and the central core wall were graded on a slope of not over 5 per cent toward the central open trench, in preparation of the work of hydraulic sluicing of the main embankment under a future contract.

Materials for the pervious fills were generally dumped from trucks, spread in layers with bulldozers, and then rolled with either a 12-ton, 3-wheel roller or with a sheep's-foot roller. The 3-wheel roller was equipped with cleats on the rear wheels. All layers were thoroughly sprinkled before and during rolling. Materials containing boulders, where rolling was impractical, were consolidated in water by local ponding.

The cofferdams were completed November 8, the upstream cofferdam to elevation 430 and the downstream cofferdam to elevation 420. The original river bed was about elevation 380. All the consolidated pervious embankments were practically completed during the year. Rock from the open-cut ledge excavation and spoil from the previously excavated stream control tunnel together with some crushed stone from the concrete aggregate plant was placed in required stone fills in the downstream toe, in drains through the downstream cofferdam and in riprap on the face of the upstream cofferdam. These rock fills were nearly completed during the year.

On May 27 the contractor took over and continued the operation of pumps in the three exploratory caissons sunk under previous contracts. From this date until the end of the year the total quantity pumped in operations for lowering the ground water level was 890 million gallons, an average of 3,296 gallons per minute. The minimum daily rate was 1,807 gallons per minute on October 26, and the maximum 4,065 gallons per minute on August 4. In addition to pumping from the three exploratory caissons which were especially equipped for this work, the contractor pumped from time to time from five other caissons. In two of these, strainers were installed in the underpinning providing equipment similar to that in the exploratory caissons. In two others, diaphrams were installed in the bottom of the caisson wells, through which pumping was done directly from the working chamber. In the other caisson pumping was done from an open sump. The contractor had in all 12 pumps in service with a total capacity of 7,460 gallons per minute. Individual pumps varied in capacity from 200 to 800 gallons per minute, the largest having a capacity of 600 gallons per minute under 230-foot head driven by 50-horsepower motor. The pumps were centrifugal, electrically driven units of the mine type. The pumping operations lowered the ground water in the deepest portion of the rock gorge to a point about 85 feet below the original water level in the river.

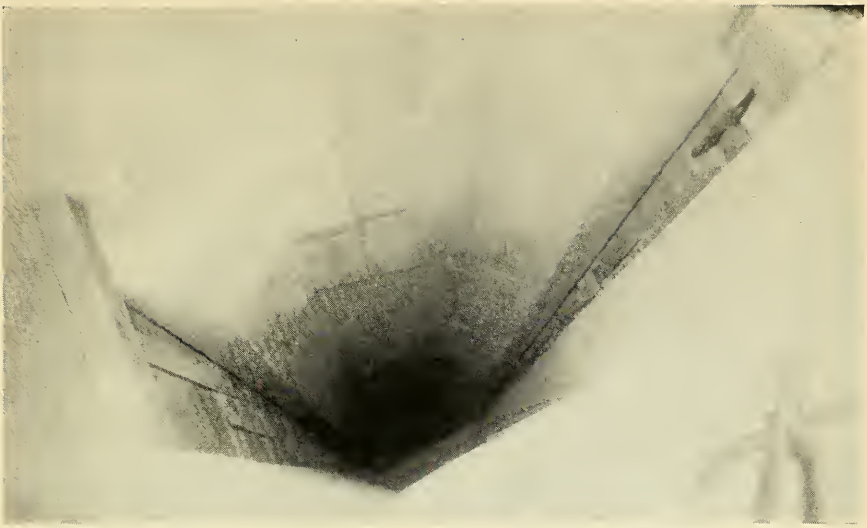
The river is diverted from its original bed into a channel paved for watertightness at a point 800 feet upstream from the core wall. The point of discharge from the downstream end of the stream control tunnel into pervious material is about 1,500 feet downstream from the core wall. The ground water has been lowered as follows:

Location	By exploratory caissons, to May 27	Additional under this contract to November 30	Total
At core wall	85 ft.	0 ft.	85 ft.
115 ft. upstream	70 ft.	2 ft.	72 ft.
500 ft. upstream	41 ft.	7 ft.	48 ft.
820 ft. upstream	23 ft.	7 ft.	30 ft.
1,700 ft. upstream	5 ft.	5 ft.	10 ft.
105 ft. downstream	71 ft.	6 ft.	77 ft.
800 ft. downstream	28 ft.	10 ft.	38 ft.
2,000 ft. downstream	4 ft.	10 ft.	14 ft.

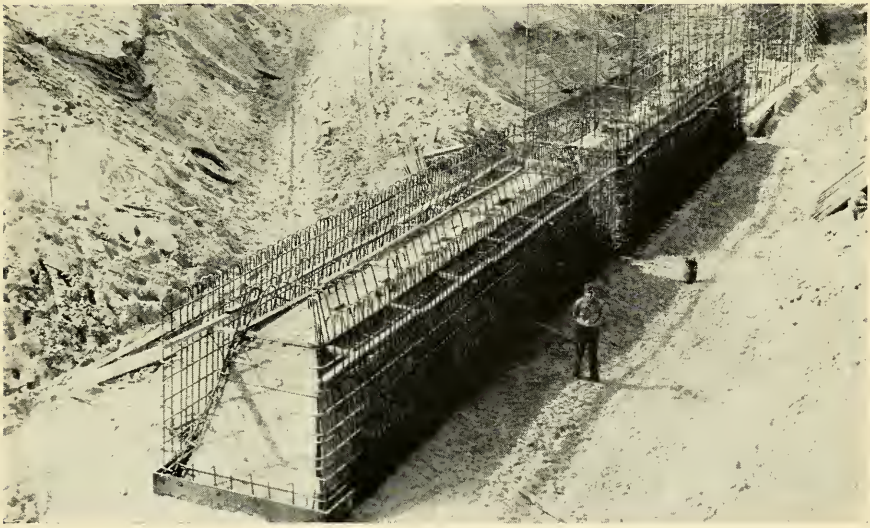
The contractor was paid for caisson excavation at bid prices for the yardage between fixed elevations independent of the air pressure required, and is paid for pumping not at a bid price but at a fixed price of 10 cents per million foot-gallons.

The caisson construction was started June 18, when the shoes of caissons 11 and 12 were set. A screening, crushing, washing and batching plant for concrete aggregates was completed June 17 at a sand and gravel borrow pit along the highway about 700 feet north of the site. Aggregates were hauled to a portable mixing plant which was set up on the edge of the open-cut trench and concrete was delivered from this plant by means of a caterpillar-mounted belt conveyor spanning the trench to the core wall. This equipment had a boom with an effective length of 65 feet which could be raised to a considerable height. A small hopper and jointed pipe hung from the end of this boom which could be raised and lowered to accommodate the surface of concrete in the forms. The first concrete was placed June 22. Caisson 12 was the first to strike water, reaching it at elevation 332 July 29. Work on the remaining caissons progressed very rapidly. The last shoe, number 1, was placed October 7. The first caisson sealed to rock was number 5 on August 23. The methods employed were in general similar to those described in previous reports in the case of the caisson core wall for the dike constructred under Contract 36. At the start of the work three air compressors with a total capacity of 2,550 cubic feet of free air per minute were used. Later a compressor with a capacity of about 600 cubic feet per minute was added. This equipment was sufficient for working three caissons simultaneously. Later, an additional compressor having a capacity of about 1,600 cubic feet per minute was installed and four caissons were worked simultaneously. Additional capacity of 400 cubic feet per minute and pressures up to 100 pounds per square inch were used to drill grout holes. High-pressure water jets were used to dislodge boulders. Concrete was generally cast in 16-foot lifts against steel forms, four sets of which were used. Caissons were sunk in dry material by the use of head frames mounted on the caisson. An electric two-drum hoist mounted on one end of a caisson handled buckets in each of the two muck shafts. The buckets were dumped over the sides of the caisson and the spoil loaded into trucks by a gasoline-driven shovel operated in the bottom of the cut. During air sinking the hoist was set up on the edge of the open cut opposite the caisson. Four sets of air locks were used. A temperature of about 70° was maintained in the working chambers.

A large percentage of the air work consisted of excavating to sound ledge after the actual sinking of the caisson was discontinued. In this operation underpinning walls about 9 inches thick were built as soon as the excavation for approximately a 3-foot depth was completed. Concrete for these walls was mixed in the working chamber by hand with aggregates lowered in the muck buckets. The depth of underpinning walls varied from 1 foot to a maximum of about 15 feet. The excavation of end joints between caissons was done generally by crews of two men each, the sides of the excavation being supported by wooden lagging spanning the extreme outer corners of adjacent caissons. A single crane handled small muck buckets for two keyways. Several of the keyways were excavated by pulling the material into the working chamber of an adjacent caisson. In keyways which required excavation under air the keyway was excavated in the open to the ground water level and a cylindrical shaft form some 3 feet in diameter installed. The concrete was then placed around this form by using the jointed pipe attached to the concrete conveyor boom, and vibrated by lowering the vibrator on a rope. An air lock was then installed the same as for the caisson itself.



Contract 38. — Looking Down Excavated Keyway Between Caissons Numbered 2 and 3.



Contract 38. — Main Dam Caisson Core Wall, Cutting Edges and Working Chamber Forms and Reinforcement, Caissons Numbered 39 and 40.

In extending the tops of caissons to the required uniform height 25 feet above the bottom of the open-cut trench the steel forms were dismantled to obtain sections of approximately the correct height. When only one or two feet of additional height were required, wooden forms were used.

Grouting from the working chambers at the bottoms of caissons was started October 23. At the end of the year preliminary grouting in 13 caissons and final test grouting in 8 caissons was completed, and 4 working chambers were sealed with concrete. In the grouting operations, 6 holes were drilled from the bottom of each caisson into the concrete seal and 20 feet into the rock. These holes were grouted using pressures up to 50 pounds per square inch. A week or ten days after grouting was completed in any area, three test holes were drilled through the seal in each caisson. Such holes were generally tight and in only a few cases did they take any grout.

At the end of the year all the caissons had been sunk except numbers 12, 14 and 19, which were nearly sunk, caissons 11 and 15 were being sealed and all others had been completely sealed. The end joints between caissons were about 70 per cent excavated and about 50 per cent completely sealed with concrete. The average rate of sinking in the open was 9.77 feet in 24 hours under atmospheric pressure, and under air 3.63 feet. The ground water was lowered to such an extent that although the maximum depth of sinking below the original ground water level was 125 feet, a pressure in excess of 18 pounds per square inch was exceeded in only five caissons, and in excess of 26 pounds in only two caissons. The maximum pressure required was 29 pounds in caisson 10 where it was necessary to work below the level of the pumping intakes in exploratory caisson number 9, thus requiring the shutting down of these pumps. Nine of the 37 caissons under this contract did not require the use of compressed air. There were 295 caisson days of pressure below 18 pounds, 36 between 18 and 26 pounds and 6 between 26 and 29 pounds.

The value of work included in contract estimates to November 15, the date of the latest estimate, was $1,021,829.00, of which 90 per cent was approved for payment. The contractor's force averaged 332 men, the maximum being 508 for the week ending August 31.

The total electric energy used by the contractor was 1,650,955 kilowatt hours.

The principal items of plant were as follows:

6 Gasoline shovels, including two with convertible booms
3 Traveling cranes
3 Bulldozers
2 Power scrapers with Diesel tractors
2 12-ton gas rollers
1 Sheep's-foot roller
1 Crushing, screening and washing plant
1 Aggremeter
1 1-cu. yd. dual drum paving mixer
1 Caterpillar-mounted concrete conveyor
4 Low pressure air compressors, total capacity 4,150 cu. ft. per min.
2 High pressure air compressors, total capacity 1,000 cu. ft. per min.
64 Ft. height of steel caisson forms
4 Man locks
4 Muck locks
1 Hospital lock
12 Pumps, as previously described
Trucks, hoists, portable compressors, drills, etc.

The total work done and materials furnished to date under the principal items of Contract 38 are as follows:

Earth excavation in open cut	224,600 cu. yds.
Rock excavation as boulders in open cut	320 " "
Rock excavation as ledge in open cut	10,800 " "
Stripping	51,100 " "
Unconsolidated embankment	8,240 " "
Consolidated pervious embankment	167,900 " "
Rolled impervious embankment in core	14,070 " "
Rolled impervious embankment not in core	18,350 " "
Stone Fills	37,750 " "
Pumping	87,600 mil. ft. gals.
Earth excavation for core wall bottom of open cut to elevation 300	31,410 cu. yds.
Earth excavation for core wall below elevation 300	2,910 " "
Rock excavation in caissons to elevation 300	2,300 " "
Rock excavation in caissons below elevation 300	350 " "
Concrete not placed under air pressure	42,150 " "
Concrete placed under air pressure	4,450 " "
Portland cement	69,310 bbls.

Contract 39.—Contract 39, for constructing a trunk sewer in the towns of Rutland and Holden, was continued to completion. There has been paid the Contractor in full settlement of all claims $238,708.67.

Contract 49.—Bids were opened September 10, for excavating diversion channels at the site of Quabbin Reservoir in the towns of Dana, Hardwick and Greenwich. Twelve bids were received, ranging from $79,050.00 to $207,155.00. The contract was executed October 2, with Cenedella & Company, Milford, Mass., the low bidder. Clearing the site of the diversion channel and spoil area between the Middle and East branches was started October 21, and the spoil area at the lower intake channel at Shaft 12, October 26.

Excavation of the lower intake channel at Shaft 12 was started November 6, using a gasoline crane with 70-foot boom and 2⅓-cubic yard drag bucket. Muck excavated from this channel was trucked to a spoil area north of the channel and suitable material from below the muck was spread over the area adjacent to the channel. This channel was completed November 16, except for some trimming of slopes.

The excavation of the channel between the East and Middle branches of the Swift River was continued, using a 90-horsepower caterpillar scraper which started work November 4. The crane previously used at the lower intake channel at Shaft 12 started on this work November 16.

The work of clearing the site of the outlet channel at Shaft 11A was started November 8.

The value of work included in contract estimates to November 12, the date of the latest estimate, was $7,300.00, of which 90 per cent was approved for payment.

The total yardage excavated to date is 10,000 cubic yards in the lower intake channel at Shaft 12 and 75,600 cubic yards in the diversion channel between the East and Middle branches of the Swift River.

Coldbrook-Swift Tunnel Division

The Coldbrook-Swift Tunnel Division, until its discontinuance October 31, continued in charge of the construction of the Coldbrook-Swift tunnel section of Quabbin Aqueduct and, until September 16, of river surveys along the Ware, Swift and Chicopee rivers.

Office Work

Tunnel cross sections were plotted and excavation and masonry volumes computed therefrom. Semi-monthly estimates and the final estimate were prepared for Contract 20. Plans and topographic maps were made of the areas at and near Shafts 11A and 12, for an access road to Shaft 12, of the Quabbin Reservoir watershed divide, and of miscellaneous areas along the Ware River. The preparation of geologic field notes and specimens for a permanent geologic record was continued. These specimens were permanently stored in the Ware River intake building.

Field Work

Lines and grades were given for construction on Contract 20. Surveys for record were made of the stop log and screen grooves in the Swift River intake at Shaft 12. About 525 acres of topography were taken along the Ware River and tributaries below the intake and in the vicinity of Shaft 12. The taking of photographs of the construction work and of rock formations of geological interest was continued. Excavation for a water supply tank for buildings at Shaft 12 was begun July 25 with a small labor force. The tank was completed September 14. The spring supplying the tank was deepened, walled up with stone and covered September 27. The distributing pipe from the tank to Shaft 12 and the temporary branch office of the division was completed October 8. Laying of the supply pipe from the spring to the tank was in progress October 31, when the division was discontinued. The labor force employed in this work reached a maximum of 14 for one week.

The collection of data pertinent to the determination of the water power available and developed at various plants on the Ware, Swift and Chicopee rivers and to the determination of flows at various points under varying conditions, and the investigation of the quality of the water in these rivers was con-

tinued until September 16, when the personnel engaged therein was transferred to the Quabbin Reservoir Division.

Progress of Contracts

Contract 20.—Contract 20, for the construction of the Coldbrook-Swift tunnel section of Quabbin Aqueduct, through the towns of Barre, Hardwick and Greenwich, was continued to completion.

During the year the work consisted principally of completing the substructure of the future head house at the top of Shaft 9; installing the ladder and platforms for access to the bottom of the shaft and constructing a chamber at the bottom of the shaft to permit the future installation, in any emergency, of a tunnel unwatering pump at this point to supplement the pump at the bottom of Shaft 1; sinking and lining Shaft 11A and constructing an outlet at the top of this shaft for the discharge into Quabbin Reservoir of water diverted from the Ware River; completing the lining of Shaft 12 and the substructure of the intake works at the top of this shaft; grouting the timbered sections of the tunnel and the 200-foot length just east of the intake at Shaft 12 which was constructed as a pressure tunnel with circular cross section; and cleaning up.

Tunnel lining was completed at Shaft 10 about the end of February and the use of bulk cement was then discontinued.

Cleaning the tunnel between Shafts 12 and 9 was done by two parties of 7 to 9 men each. The work progressed downstream to take advantage of water flowing on the invert. Small portable wooden dams about 12 inches high were placed across the invert 200 or 300 feet apart, the section cleaned with brooms and then flushed by removing the dams. Heavy material was shoveled into buckets and transported by an automobile truck driven by electric storage batteries. The contractor continued to employ local physicians who made weekly reports on the health of his employees and on the sanitary conditions of each of his camps.

The value of work included in contract estimates during the year was $205,339.44, the final estimate dated October 1, being for $4,809,852.83.

Shaft 9.—The work of concreting the emergency pump chamber at the bottom of this shaft was completed January 5. The contractor then installed pumps in this shaft to maintain the entire tunnel in a dry condition. The work of placing the steel ladder and platforms in the shaft was begun about April 15. The extension at the top of the shaft of the 20-inch emergency pump discharge line embedded in the shaft lining was completed May 6. The contractor thereafter used this pipe, with a temporary 50-foot extension, as a discharge line for his tunnel pumps. To complete the concrete work at the top of the shaft a temporary concreting plant was set up north of the shaft. Excavation for the spillway was started May 13, the wing walls and head walls of the culvert being carried down to sound rock. Masonry work for the spillway outlet was completed July 13, and paving at the outlet was completed August 20. All equipment was removed from the shaft and the headframe taken down June 18. Pumping in the tunnel was discontinued August 8. Work on the access road was started about July 5 and completed about August 28. Cleaning up débris from the camp sites, removing plant and equipment, grading borrow pits, etc., was completed September 26. All work at the shaft was practically completed September 14. The contractor's force averaged 10 men, the maximum being 35 during the week ending August 3. The contractor's camp at this plant was unoccupied except by a watchman.

Shaft 10.—The tunnel lining, consisting of 521 feet easterly and 499 westerly, was continued to completion February 20. The precast beams and slabs for closing the top of the shaft were cast about April 10. Grouting of vent holes in the tunnel arch at this shaft was started April 15 and completed May 2. All equipment was removed from the shaft and the site, and the headframe taken down July 23. The concrete top of the shaft was completed August 3, and grading over the shaft August 13. All work at this shaft was practically completed September 28. On December 3, 1934, the dry house and contractor's office building were destroyed by fire. These buildings were not replaced but alterations were made in other buildings to give the necessary accommodations.

The contractor's force averaged 16 men, the maximum being 60 during the week ending September 8. The average number of persons occupying the camp was 12 until January 12, after which the camp was unoccupied except by a watchman.

Shaft 11.—Grouting of the timbered sections and vent holes in the tunnel roof at this shaft was started May 2 and completed about May 20. Concreting the shaft connection at the bottom of the shaft was completed June 11. The headframe was removed July 14. The concrete top of the shaft was completed and the precast beams and slabs placed August 1. Equipment was removed and all grading and cleaning up at the top of the shaft were completed August 8. All work at this shaft was practically completed August 17. The contractor's force averaged 6 men, the maximum being 27 during the week ending July 13. The contractor's plant at this camp was unoccupied except by a watchman.

Shaft 11A and Ware River Outlet.—The contractor started December 3 to drive an 8-inch casing to ledge and to drill a 6-inch hole to the tunnel on the center line of this shaft, in order to drain the ground water interfering with his excavation into the tunnel. This hole reached the tunnel January 6. Excavation of the outlet channel was resumed February 25 and completed about March 25. About March 10, the contractor set up a derrick and compressed air hoist and started shaft excavation March 25. After some difficulty with fine running sand, ledge was reached April 6. The excavation was continued through about 80 feet of rock, breaking through into the tunnel April 26. A concreting plant was set up at the edge of the excavation. Cement in bags was hauled from Greenwich Village, sand from a borrow pit on the highway nearby, and stone from the aggregate pile at Shaft 10. Concrete lining of the shaft in rock was poured from May 6 to May 29. The extension at the top of the shaft containing the outlet passages and culvert to the reservoir was completed July 11. Stone masonry in the culvert wing walls and head wall was completed July 5. Back filling, paving and riprap were completed August 5. All work at this shaft was practically completed August 17. The contractor's force averaged 12 men, the maximum being 26 during the weeks ending May 11 and 25. No provision was made for the housing of contractor's employees at this shaft, the camp being occupied by only a watchman.

The principal items of plant were as follows:

1 Derrick with 52-ft. boom
1 Compressed air hoist
2 Air compressors, each having a total capacity of 550 cu. ft. per min. and driven by 125 H.P. motor
1 1-cu. yd. concrete mixer
3 Pumps, the largest having a capacity of 1,700 gals. per min. under 50-ft. head with 15 H.P. moto

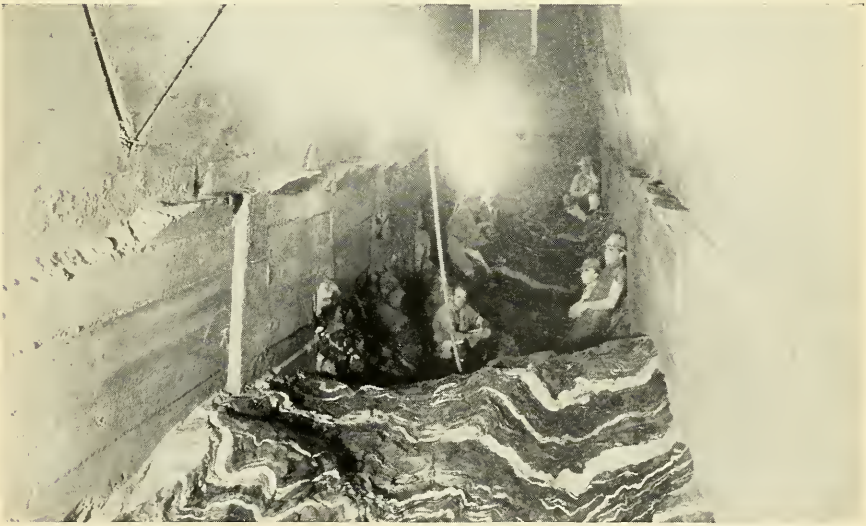
Shaft 12 and Swift River Intake.—Placing concrete in the shaft lining and head house substructure was continued at this shaft. Construction was carried on inside a steam-heated wooden shelter covering the entire working space at the top of the shaft to allow laying of stone masonry to continue in cold weather. This shelter and the derrick were raised to include the upper part of the structure between January 18 and February 2. Construction of stone masonry wing walls was commenced December 15, 1934. Stone and concrete work in the head house substructure was continued to completion May 4.

Grouting of the circular or pressure section of the tunnel just east of the shaft and grouting of the shaft itself was started April 13 and completed May 13. Excavation of the upper intake channel was started May 6. Material was deposited in the approach fill to the shaft and was consolidated with water to reduce the amount of future settlement. To complete this fill, additional material was obtained from a borrow pit below the flow line. The placing of crushed stone from the aggregate pile and riprap and paving from the upper intake channel excavation and from miscellaneous borrow areas was completed July 27. The paving adjacent to the substructure and wing walls was grouted. Practically all the work at this shaft was completed August 31. The contractor's force averaged 21 men, the maximum being 38 for the week ending March 9. The contractor's camp at this plant was unoccupied except by a watchman.

There was no material change in plant items during the year.

The total work done and materials furnished under the principal items of Contract 20 are as follows:

Contract 38. — General View of Caisson Core Wall Looking East Across Main Dam Site.



Contract 38. — Main Dam Caisson Core Wall, Underpinning to Sound Rock in Working Chamber of Caisson Number 5.

	Shaft 9	Shaft 10	Shaft 11	Shaft 11A	Shaft 12 and Intake
Earth excavation for shafts (cu. yds.)	85	319	225	339	*
Rock excavation in shafts and in tunnel within 50 feet of shafts (cu. yds.)	2,366	3,656	2,275	409	1,432
Excavation in tunnel, except within 50 feet of shafts (cu. yds.)	101,791	105,873	105,989	0	60,620
Shaft and tunnel drainage (lin. ft.)	16,964	16,788	15,918	110	8,905
Earth excavation in open cut (cu. yds.)	1,548	2,137	1,804	3,155	42,809
Rock excavaton in open cut (cu. yds.)	35	439	106	26	2,730
Forms for concrete lining in shafts (lin. ft.)	196	410	270	104	0
Forms for concrete lining in tunnel (lin. ft.)	13,652	16,738	15,348	0	9,090
Concrete masonry in shafts (cu. yds.)	744	1,141	810	327	0
Concrete masonry in tunnel (cu. yds.)	28,579	35,880	32,256	0	19,095
Concrete masonry not in shafts or tunnel (cu. yds.)	101	0	1	148	2,959
Permanent timbering in tunnel (M ft. B.M.)	37	231	55	0	29
Temporary timbering in tunnel (M ft. B.M.)	11	6	5	0	0
Portland cement (bbls.)**	47,100	59,600	53,200	760	35,330
Steel for reinforcing concrete (lbs.)	7,892	1,137	1,137	20,492	139,573
Gunite protective coating of tunnel rock (lin. ft.)	3,994	3,661	0	0	0
Refilling and embanking (cu. yds.)	2,697	5,040	569	2,459	16,456
Miscellaneous cast iron, wrought iron and steel (lbs.)	53,935	3,924	485	6,857	229,361
Riprap (cu. yds.)	—	—	—	252	2,568
Paving (cu. yds.)	95	—	—	13	561

* Included in item "Earth excavation in open cut."
** Cement proportioned to concrete masonry at each shaft.

Electric power for all contract requirements was purchased by the contractor. The total consumed at the different shafts during the year was as follows:

	K.W.H.
Shaft 9	441,600
Shaft 10	335,800
Shaft 11	392,600
Shaft 11A	76,500
Shaft 12	195,400
Total	1,441,900

The total electric power consumed on Contract 20 from beginning of work April 23, 1931 to the removal of the power line October 1, 1935 was 24,549,269 kilowatt hours, the total length of tunnel excavated being 54,831 linear feet and the total length of tunnel lined being 54,862 linear feet.

Quabbin Reservoir Division—Enfield Office

The Quabbin Reservoir Division continued in charge of the field work in the Swift River valley in connection with the proposed Quabbin Reservoir including topographic and real estate surveys, cemetery removals, and the soil testing and water analysis laboratories. On September 16 this division took charge of the investigations, surveys, etc. along the Ware, Swift and Chicopee rivers. This division also continued in charge of construction work at the dike site and of the construction of the Daniel Shays Highway, formerly referred to as the Belchertown-Pelham highway and its extensions.

Miscellaneous Office Work

Semi-monthly estimates for Contract 50, monthly estimates for Contract 23, and the final estimates for Contracts 23, 36, 41, 43 and 44 were prepared. Topographic maps were prepared and studies made of possible highway relocations northerly and easterly of Quabbin Reservoir. Record plans and tracings were prepared of the Ware-Belchertown highway constructed under Contract 21 and the Belchertown-Pelham highway constructed under Contract 41. Revised topographic plans of the main dam site and its vicinity were made. Photographs of the progress of construction carried on under the supervision of this and other divisions were taken. Meteorological records at Enfield were continued.

Miscellaneous Field Work

Lines and grades were given for construction on Contracts 23, 43, and 50. Daily readings of the ground water level and numerous test wells were continued

during the pumping operations at the dike, and until December 15, 1934, at the main dam. Following the diversion of Beaver Brook above the dike April 12, the depth of water upstream from the dike gradually increased until at the end of the year it stood 6.75 feet above the original surface of Morton Pond, and within 10.25 feet of the point at which the flow will be diverted northerly into the Swift River.

Necessary data on topographic and other features were taken in connection with the studies for highway relocation.

Reservoir-General

Topography.—Topography in the vicinity of the flow line of the reservoir was completed. To date 30,320 acres or 47.4 square miles have been surveyed for the general topographic maps within and adjacent to the proposed reservoir, including the topographic location of the entire flow line. About 47.3 miles of the Swift River watershed divide was surveyed, making a total to date of 67.7 miles, 11.9 miles of which was surveyed by the Coldbrook-Swift Tunnel Division.

Real Estate.—Properties described in applications by owners for sale of real estate were located and when no surveys had been made sketches showing the approximate location were prepared. Comprehensive real estate surveys and analyses and descriptions of deeds were continued. Real estate surveys during the year cover 4,106 acres, making a total to date of 64,107 acres or 100.17 square miles. Of this total, 62,258 acres have been plotted on a scale of 1 inch = 200 feet. No additional final tracings were made.

Photography.—The photographing of buildings and cemetery lots within the area to be affected by the proposed reservoir was continued. During the year 73 photographs of buildings and 365 of miscellaneous views and of the progress of construction carried on under the supervision of this and other divisions were taken. Also, 99 photographs of property in the Ware River watershed were taken.

Cemetery Removals.—Interments in Quabbin Park Cemetery and the general removal of bodies from existing cemeteries in the reservoir area were continued. The removal of bodies, headstones and monuments has been done with labor engaged directly for this work. During the year work progressed as shown in the following table:

CEMETERY REMOVALS

		To Nov. 30, 1934†	Year Ending Nov. 30, 1935	Total
Burial lots in Quabbin Park Cemetery assigned in exchange		441	80	521
Burial lots in Quabbin Park Cemetery sold		15	5	20
Number of releases executed of rights in old lots in Quabbin Reservoir area	to Q. P. Cemetery	212	80	292
	to other cemeteries	136	22	158
Bodies removed from Quabbin Reservoir area	to Q. P. Cemetery	1,126	514	1,640
	to other cemeteries	786*	39	825*
Bodies removed from area outside Quabbin Reservoir to Quabbin Park Cemetery		2*	1	3*
Burials, not reinterments, in Q. P. Cemetery		54	17	71
Headstones moved	to Q. P. Cemetery	672	256	928
	to other cemeteries	362	22	384
Monuments moved	to Q. P. Cemetery	121	54	175
	to other cemeteries	131	7	138

† Quabbin Park Cemetery was not completed ready for use until August 25, 1932, prior to which time 632 bodies had been removed to other cemeteries.

* Includes one body originally moved outside and then back to Quabbin Park Cemetery.

The vault was maintained in readiness for use during the winter months. Work of developing Quabbin Park Cemetery was continued by grading and seeding miscellaneous areas outside the established lots and by miscellaneous clearing and grubbing where trees interfered with the setting of stone. Cemetery lots were graded and seeded as removals were completed and in the case of purchases were graded and seeded at once. The average force employed on cemetery development during the working operations was 13 men, the maximum being 16 during the week ending May 25.

Fire Protection.—The fire fighting equipment was continued in readiness for service at all times. Five assistants in the division office were reappointed as deputy forest wardens in each of the towns affected by the reservoir. The equip-

ment and personnel responded during the year to calls for assistance at 16 forest fires which burned over a total area of about 1,178 acres. The large acreage involved was due to two large fires of incendiary origin set during a period of unusual fire hazard conditions. There also occurred a total of 23 fires in buildings, 8 of which were chimney fires resulting in little if any damage.

Lumbering.—The New England Box Company continued its cutting operations under agreements with the Commission for the purchase of standing timber. The lumber was stacked as cut and hauling away commenced July 17 and continued throughout the year. During the year about 4,790,500 ft. B.M. were cut, and about 4,247,000 ft. B.M. were hauled, the corresponding totals to date being about 9,210,500 ft. B. M. cut and 5,775,000 ft. B.M. hauled. In addition, miscellaneous standing timber at various places throughout the valley has been sold to other operators and cut under the general supervision of this division.

Reforestation.—The general program of reforestation was started during the spring with nursery stock obtained from the Clinton and Amherst nurseries of the Department of Conservation. Planting of three-year-old red and white pine was commenced April 19 on approximately 420 acres on the middle and lower portions of the "Prescott Peninsula," and was confined to open areas requiring no clearing. A total of about 500,400 trees were planted and there has been but slight loss to date. Two-year-old white pine seedlings were planted early in May in a temporary nursery covering about two acres of previously cultivated land in Greenwich. A total of about 511,000 seedlings were planted with but little loss to date. Red pine and Norway spruce seedlings were planted in the latter part of May in a nursery covering about two acres in Ware east of Beaver Brook and just north of highway route 9. This area had been under cultivation the previous season and was prepared in the early spring by careful plowing and harrowing. About 288,800 red pine seedlings were planted, of which less than 50 per cent survived a fungus blight. About 53,300 Norway spruce seedlings were planted with but little loss to date. In preparation for nursery planting during the coming year, an area of four acres in Enfield adjacent to highway route 21 was plowed.

Clearing.—Outside of the lumbering operations referred to above no general clearing of the reservoir site has yet been done. However, fire stops have been established by cutting strips 100 feet wide just inside the clearing line established at the future flow line of the reservoir. Such fire stops have been cleared on the easterly slopes of the West Branch of the Swift River extending northerly from the village of Enfield, approximately 5 miles. The flow line has also been cleared on the easterly side of Beaver Brook valley for a distance of about one mile north of the dike. This work was started April 17 and continued throughout the year. Labor was engaged to clean up and burn the refuse left following the sale and removal of buildings in the towns of Prescott, Pelham, Belchertown and Enfield.

Soil Testing Laboratory.—The work of exploring, collecting and testing materials to determine their suitability for use in the construction of the proposed main dam and dike was continued. New equipment was added to the laboratory as testing methods were expanded to include new studies and to keep pace with current developments in soil engineering. Investigations were continued of the glacial deposits in prospective borrow areas north of the main dam site. Similar investigations were continued of materials at the suggested site for the East Branch baffle at Greenwich Village. Tests were continued of topsoils for impervious refill in connection with the work under Contracts 38 and 50. Routine control tests were continued to determine the density, moisture, organic content and permeability of the impervious soil refill placed under these contracts. Use of the plasticity needle was continued in these tests. Routine permeability and sizing tests were made of samples from the consolidated pervious embankments placed under Contract 38, and from the hydraulic fill constructed under Contract 50. The latter included frequent tests of the borrow pit and sluiced material and water in the pool, for the control of the quality of the beach and core materials. Tests were continued of concrete aggregates, concrete and other miscellaneous materials used in the construction work of this and other divisions.

Chemical and Bacteriological Laboratory.—The analyzing of industrial wastes and the collecting and analyzing of water samples were continued in cooperation with the headquarters office and with assistance from the Coldbrook-Swift Tunnel Division. On September 16 this division took charge of the collection of stream flow, water power and other data pertinent to mill and water power damages previously in charge of the Coldbrook-Swift Tunnel Division. Samples of water supplies of contractors engaged on work in this and other divisions and of miscellaneous supplies on property controlled by the Commission were collected and analyzed periodically.

Progress of Contracts

Contract 23.—Contract 23, for making borings in the towns of Belchertown, Enfield, Ware, Greenwich and Hardwick, was continued to completion. During the year the work consisted principally of the exploration of proposed borrow areas for materials to be used in construction.

The value of work included in contract estimates during the year was $7,331.72, the final estimate dated September 11 being for $59,044.29. The contractor had one drilling rig in operation during the year and employed an average of two men.

Under this contract 384 holes were drilled. The total depth drilled was 18,791 feet, of which 15,740 were in overburden and 3,051 in bedrock. In addition, 167 holes were abandoned by the contractor on account of the difficulty of penetration of the over-burden.

Contract 36.—Contract 36, for constructing a core wall to sound rock at the site of the dike of Quabbin Reservoir in the towns of Enfield and Ware was continued to completion. At the close of the preceding year there remained but little work to be done under this contract. A small quantity of impervious fill adjacent to the easterly end of the core wall was made and the final work of cleaning up was completed December 12, 1934. At the main dam pumping was continued under this contract in the two exploratory caissons together with pumping from exploratory caisson numbered 20, sunk under Contract 32. This pumping was taken over by the Commission December 16 when the total rate of pumpage was about 5,000 gallons per minute. The total electrical power consumed at the dike site from the beginning of the work was about 3,300,400 kilowatt hours.

The value of work included in contract estimates during the year was $48,089.34, the final estimate dated December 22, 1934, being for $1,151,602.49. The contractor's force averaged 15 men for five weeks ending January 5, the maximum being 43 for the week ending December 8, 1934.

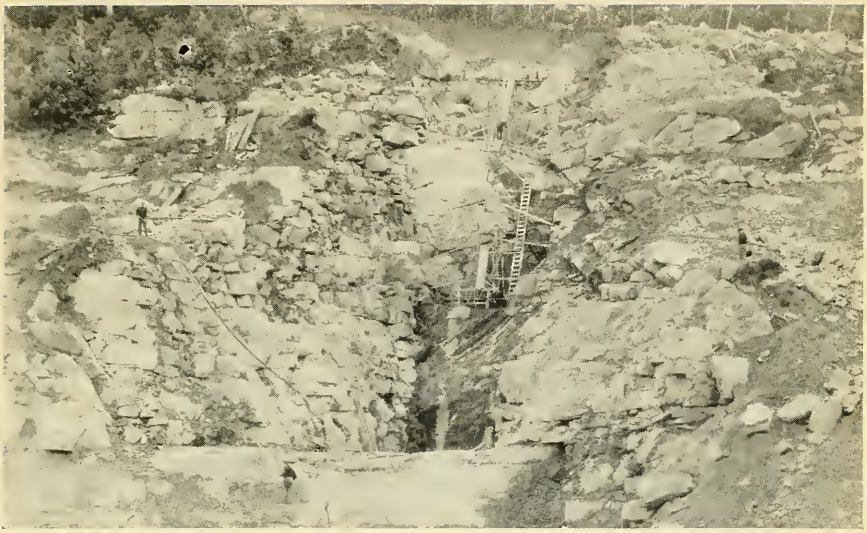
No important items of plant were added during the year.

The total work done and materials furnished under the principal items of Contract 36 are as follows:

Earth excavation in open cut to elevation 400	284,555 cu. yds.
Earth excavation in open cut below elevation 400	53,000 " "
Rock excavation as boulders in open cut	1,610 " "
Rock excavation as ledge in open cut	4,030 " "
Stripping	85,150 " "
Unconsolidated embankment	35,420 " "
Consolidated pervious embankment	236,405 " "
Rolled impervious embankment	130,245 " "
Pumping	229,420 mil. ft. gals.
Earth excavation for core wall, bottom of open cut to elevation 310	30,065 cu. yds.
Earth excavation for core wall below elevation 310	2,000 " "
Rock excavation in caissons to elevation 310	2,025 " "
Rock excavation in caissons below elevation 310	1,060 " "
Concrete not placed under air pressure	38,855 " "
Concrete placed under air pressure	5,105 " "
Impervious filling in caisson shafts	3,435 " "
Drilling holes in rock or masonry	10,005 lin. ft.
Furnishing and placing grout	545 cu. yds.
Portland cement	72,995 bbls.
Riprap	4,575 cu. yds.

Contract 41.—Contract 41, for constructing a portion of the Belchertown-Pelham highway in the towns of Belchertown and Pelham, Hampshire County, was completed November 20, 1934.

The value of work paid for during the year was $29,418.05, the final estimate dated November 20, 1934 being for $248,578.14, of which $118,486.97, cover-



Contract 50. — Excavation for Cut-off Wall in Ledge at West End of Dike.

Contract 50. — Looking East Along Center Line of Dike Embankment Under Construction by Hydraulic Sluicing, Central Pool at Elev. 429.

ing mainly surfacing items and guard rail, was assumed by the Department of Public Works.

Contract 43.—Contract 43, for constructing an extension of the Belchertown-Pelham highway to New Salem Center in the towns of Shutesbury and New Salem, Franklin County, was practically completed early in the year. The work consisted of setting property bounds, completing guard rail, installing blind drains in wet slopes and constructing additional cobble gutters.

There has been paid the Contractor $376,964.65 and there remains to be paid in full settlement of all claims $10,640.82. The Department of Public Works has paid, mainly for surfacing items and guard rail, $101,705.13 of the above and will further reimburse the Commission in the sum of $18,862.76.

Contract 44.—Contract 44, for constructing an extension of the Belchertown-Pelham highway north of New Salem Center in the towns of New Salem and Orange, Franklin County, was completed November 20, 1934.

The value of work paid for during the year was $17,091.36, the final estimate dated November 20, 1934 being for $199,940.12, of which $63,222.73, covering mainly surfacing items and guard rail, was assumed by the Department of Public Works.

Contract 50.—Bids were opened November 13, 1934, for constructing the embankment of the dike of Quabbin Reservoir in the towns of Enfield and Ware. Six bids were received ranging from $1,446,655.00 to $2,267,962.50. The contract was executed December 5, 1934, with the Arthur A. Johnson Corporation, Long Island City, New York, the low bidder. The work under this contract includes completing the foundation work on the hillsides of the dike abutments where excavation had been started under Contract 36, placing impervious and pervious materials required to build the foundations of the dike high enough to satisfactorily permit embankment construction by the full hydraulic method, constructing the main portion of the dike by the full hydraulic method, placing riprap on the upstream face, dressing with soil and grassing the downstream face, and constructing permanent access roads.

On December 17 the contractor took over the maintenance of the engineers office at the dike site and soon after installed a new water supply for office use downstream from the dike.

On February 18 work was started on the removal of unsound ledge from the west abutment and also on the clearing of wooded areas to be used as borrow pits. Work of grading access roads was started April 1. On April 8 work was started placing rolled fills for grading preparatory to filling by hydraulic sluicing. These fills consisted of pervious material on the outer portion of the dike, semi-impervious near the core and impervious topsoil for the core in the center. For the most part these fills were placed in layers and rolled with a tractor-drawn, sheep's-foot roller, each layer after rolling being not over six inches in thickness. Extremely coarse material was placed by puddling in water. These fills were continued to practical completion during the last week in August.

Approximately 7,000 cubic yards of broken and seamy ledge was removed from the west abutment uncovering sound rock on the center line. This was covered with a fairly massive concrete blanket and the ledge thoroughly grouted. A strip of ledge was uncovered at the east abutment and a concrete blanket 20 feet wide was poured over a portion of the area uncovered during the season. The ledge encountered in the east abutment was found to be in excellent condition and it was necessary to remove but comparatively small quantities to reach sound rock. This ledge was also thoroughly grouted.

The pumping equipment which had been maintained for lowering of ground water in the high shaft of caisson 7 and in one shaft of caisson 13, as described in the previous report, was removed and all suction intakes carefully grouted. These shafts were then filled with topsoil carefully compacted. A three-foot steel cylinder equipped with observation ports was installed on top of the center shaft of caisson 13 and this cylinder is being carried up through the core to permit observation of the consolidation of the core during and after construction.

The 18-inch pipe line through the upstream cofferdam which had been installed under Contract 36 for the purpose of draining Beaver Brook through the dike site was plugged during the latter part of April. To date, Morton and

Train ponds formerly in the drainage area of Beaver Brook have not risen sufficiently high to cause a flow northerly to the Swift River. The increased elevation and capacity of Morton Pond have provided the contractor with sufficient make-up water to carry on his hydraulic fill operations.

The contractor secured most of the impervious topsoil required from a borrow area lying northeasterly and upstream from the dike, pervious materials and concrete aggregates from a borrow area southwesterly of the dike site, and the large quantity of material required for the hydraulic fill embankment from a borrow area northwesterly of and upstream from the dike. Early in the spring the contractor started work on construction roads to the various pits and prepared an area for the erection of a mixing chamber, or hog box so-called, on the westerly hillside just upstream from the center line of the dike.

The hydraulic fill was started on August 26 and continued throughout the year, the contractor working continuously except for Sundays with three eight-hour shifts. Material for the hydraulic fill was excavated by three 1¾-cubic yard shovels in the borrow pit, two electrically operated and one gasoline driven. Large boulders encountered in the pit was in general hauled to the beaches of the embankment of the dike, where they were spread in the path of the wash from the sluicing pipes and became a permanent part of the fill.

Bottom dump trucks of 8 cubic yards capacity were used for the most part in hauling material to the hog box, over which a trestle had been built with a hopper of about 20 cubic yards capacity into which the trucks were dumped. Above this hopper a grizzly of iron bars spaced about two feet apart removed the largest boulders, and below it a rotary grizzly supplied by two reciprocating feeders removed all stones greater than eight inches in diameter. The rejected stones were hauled by a gasoline-driven locomotive a short distance to a temporary dump. Material passing through the rotary grizzly entered the chute of the hog box, where it was mixed with water and distributed through the sluice pipes, alternately along the upstream and downstream shoulders of the embankment. A booster dredge pump with a capacity of 12,000 gallons per minute was installed in the sluice line near the hog box and was used continuously except during the early filling at low levels.

Water for the hog box was pumped from the pool in the core section of the dike from a pump float by three electrically operated centrifugal pumps, two of 2,000 and one of 8,000 gallons per minute capacity through a discharge line of 24-inch spiral welded pipe. Prior to the operation of sluicing, the core pool was filled by a pump of 2,000 gallons per minute capacity located upstream from the dike on Morton Pond. The deficiency in water in the core pool was made up from time to time by this pump.

The discharge sluice lines to the beaches from the hog box and dredge pump consisted of 20-inch slip-joint steel pipe. As a rule, the discharge was carried across the valley throughout the length of one beach by adding or taking off one length of pipe at a time before shifting to the other beach for a similar operation. The discharge lines being on the shoulder or outer limits of the beaches, coarse material deposited near the pipe discharge was moved by draglines to form a suitable levee along the outer slope of the embankment in advance of the sluicing. Other materials were deposited varying in size from gravel near the discharge lines to fine sand near the limits of the pool, the extreme fine material going into the core pool to be settled out as the core of the dike. Velocities on the beaches were controlled by the use of numerous baffle boards to prevent gullying of the beach and to secure a proper gradation of materials. By the end of the year approximately 25 per cent of the material required to be placed by hydraulic methods had been placed in the embankment. The greater part of the westerly access road to the top of the dike and of the easterly access road leading to the easterly end of the dike was graded.

The value of work included in contract estimates to November 15, the date of the latest estimate, was $400,463.00, of which 90 per cent was approved for payment. The contractor's force averaged 119 men, the maximum being 212 for the week ending November 2. Camp facilities have not been provided at the work.

Electric power for all contract requirements was purchased by the contractor. The total consumed was approximately 1,225,700 kilowatt hours.

The principal items of plant were as follows:

3 Gasoline and 2 electric shovels
1 Traveling crane
13 Trucks, mostly 8 cu. yd., bottom dump
3 Bulldozers
2 Sheep's-foot rollers
1 Hog box with twin horizontal feed to rotary grizzly
1 20-inch dredge pump, 12,000 gals. per min. capacity, driven by 1,000 H.P. electric motor
1 Pump float
4 Electrically driven centrifugal pumps, varying in capacity from 2,000 gals. per min. at 90 ft. head to 8,000 at 120 ft. head
4,000 Feet 20-inch pipe slip joints, 20-ft. lengths
1,800 Feet of spiral welded pipe from 10 to 24 inches diameter
1 Crushing, screening and washing plant
1 1-Cu. yd. concrete paver
Gasoline locomotives, dump cars, etc.

The total work done and materials furnished to date under the principal items of Contract 50 are as follows:

Clearing and grubbing	65 acres
Earth excavation	37,000 cu. yds.
Rock excavation for core wall	7,150 " "
Rock excavation except for core wall	2,100 " "
Consolidated pervious foundation embankment	155,400 " "
Rolled impervious embankment in core	47,400 " "
Rolled impervious embankment except in core	61,000 " "
Embankment by full hydraulic method	518,500 " "
Miscellaneous embankment	9,400 " "
Selected coarse material	19,000 " "
Crushed stone or screened gravel	2,000 " "
Gravel sub-base for roads	1,500 " "
Furnishing and placing grout	540 " "
Portland cement	7,980 bbls.
Concrete, Class A	3,430 cu. yds.
Concrete, Class B	15 " "
Miscellaneous steel and iron	24,800 lbs.

Boston and Albany Railroad—Athol Branch.—Under its agreement with the Commission for the removal of tracks in the Quabbin Reservoir area, the Boston and Albany Railroad Company discontinued the public use of the Athol Branch from Bondsville to Athol June 1 on which date the last public train was operated over this line.

Work of removal of rails and appurtenances of salvage value was started June 3, at the Athol end of the line and completed July 31, to a point 0.78 mile northerly from the West Ware railroad station and located 0.10 mile below the site of the main dam. A total of approximately 23.9 miles of the line has been removed effecting complete removal in the Quabbin Reservoir area.

The line from Bondsville to the main dam is being maintained in order that equipment and materials to be used in construction work may be brought in by rail.

Throughout its operation of removal an average of 35 men were employed by the railroad company.

Geological Data

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State." A geological report is appended hereto.

List of Drawings and Tables Appended Hereto

Location of Real Estate Acquired for Quabbin Reservoir.
Takings of Real Estate (and Water Rights).
Status of Contracts Completed between November 30, 1934, and November 30, 1935; and in Force on November 30, 1935.
Canvass of Bids; Contract 38.
Canvass of Bids; Contract 49.
Construction Progress Coldbrook-Swift Tunnel Section of Quabbin Aqueduct.
Monthly Rainfall at Stations on Ware and Swift Watersheds, 1935.
Summary of Rainall on Ware and Swift Watersheds.

For data on contracts completed prior to November 30, 1934, see sixth to ninth annual reports, inclusive. A General Plan and Profile of the Present and Proposed Metropolitan Water Supply is included in the appended geological report.

Respectfully submitted,
FRANK E. WINSOR, *Chief Engineer.*

20 Somerset Street, Boston, Mass.
January 2, 1936.

FINANCIAL STATEMENT OF THE METROPOLITAN DISTRICT WATER SUPPLY COMMISSION

Expenditures and Disbursements for the Fiscal Year and from July 28, 1926, the Date of the Appointment of the Commission

General Overhead

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Administration, *Commissioners' Office:*		
Salaries, Commissioners	$10,500.00	$96,415.57
Salaries, Clerical	11,847.31	96,614.21
General Legal Expense	0.00	1,502.80
Furniture and Fixtures	116.67	2,926.22
Rent and Upkeep	2,337.12	20,491.79
Automobile Purchase	0.00	2,464.90
Automobile Maintenance	256.82	2,729.71
Miscellaneous Expense (undistributed)	1,123.80	13,073.27
Advertising	1,853.40	7,994.35
Printing and Blueprinting	680.26	9,131.38
Stationery and Office Supplies	241.94	2,085.15
Postage	132.00	1,129.30
Total Administration, Commissioners' Office	$29,089.32	$256,558.65
Engineering, *Headquarters' Office:*		
Salaries, Engineering	$81,223.76	$700,441.24
Salaries, Clerical	9,634.13	83,595.33
General Consultant Expense	0.00	116,515.25
General Legal Expense	0.00	53,160.29
Furniture and Fixtures	344.15	14,094.29
Laboratory Equipment	0.00	1,961.00
Laboratory Supplies	0.00	2,071.94
Rental of Equipment	0.00	3,370.02
Engineering Instruments	1.43	1,084.06
Rent and Upkeep of Boston Office	10,323.71	93,703.47
Rent and Upkeep of Springfield Laboratory	0.00	3,950.54
Automobile Purchase	0.00	3,151.60
Automobile Maintenance	255.73	3,617.99
Special Experiments	0.00	2,304.63
Miscellaneous Expense (undistributed)	559.69	20,668.87
Printing and Blueprinting	550.97	13,938.10
Stationery and Office Supplies	498.49	5,075.22
Postage	277.00	1,808.58
Total Engineering, Headquarters' Office	$103,669.06	$1,124,512.42
Unassigned:		
Unassigned Supplies and Equipment	$393.54	$956.96
Total Unassigned	$393.54	$956.96
Total General Overhead	$133,151.92	$1,382,028.03

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Distribution of General Overhead		
Administration, *Commissioners' Office:*		
Wachusett-Coldbrook Tunnel	$3,400.21	$76,080.12
Coldbrook-Swift Tunnel	6,135.66	27,961.78
Quabbin Reservoir	10,309.56	95,450.20
Main Dam	5,290.70	23,675.89
Beaver Brook Dike	3,953.19	24,700.38
Southern Sudbury Emergency Supply	0.00	8,690.28
Total Administration, Commissioners' Office	$29,089.32	$256,558.65
Engineering, *Headquarters' Office:*		
Wachusett-Coldbrook Tunnel	$12,367.86	$305,927.46
Coldbrook-Swift Tunnel	20,834.70	108,043.44
Quabbin Reservoir	36,392.20	496,715.55
Main Dam	20,023.83	87,533.11
Beaver Brook Dike	14,050.47	92,884.89
Southern Sudbury Emergency Supply	0.00	33,407.97
Total Engineering, Headquarters' Office	$103,669.06	$1,124,512.42
Wachusett-Coldbrook Tunnel Section of Quabbin Aqueduct, Ware Supply		
General Overhead:		
Administration	$3,400.21	$76,080.12
Engineering	12,367.86	305,927.46
Total General Overhead	$15,768.07	$382,007.58
Engineering:		
Salaries, Engineering and Clerical	$1,483.13	$394,373.50
Consultant Expense	37.50	7,649.86
Labor	6.00	2,015.33
Furniture and Fixtures	0.00	2,240.89
Engineering Instruments	–200.00	7,555.47
Rent and Upkeep	32.14	16,804.36
Automobile Purchase	157.00	11,422.82
Automobile Maintenance	80.72	15,178.90
Contracts for Investigations and Surveys	0.00	18,640.69
Miscellaneous Expense (undistributed)	23.56	9,201.91
Advertising	0.00	6.05
Printing and Blueprinting	1.06	1,058.93
Stationery and Office Supplies	2.90	2,965.93
Postage	0.00	434.81
Total Engineering	$1,624.01	$489,549.45
Real Estate, *General Construction:*		
Legal and Expert Expense	$337.26	$6,186.92
Consultant Expense	0.00	455.66
Labor	86.70	1,711.20
Miscellaneous Expense (undistributed)	0.00	1,003.60
Printing and Blueprinting	10.54	60.92
Purchases and Settlements	0.00	122,989.16
Taxes	228.36	3,494.03
Maintenance of Real Estate	114.03	1,107.97
Police Protection, Labor	0.00	41.00
Fire Protection, Equipment	0.00	30.97
Miscellaneous Expense	0.00	0.54

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Special Agents, Salaries	$0.00	$12,949.00
Furniture and Fixtures	0.00	117.67
Automobile Purchase	0.00	1,222.50
Automobile Maintenance	0.00	2,124.30
Miscellaneous Expense (undistributed)	0.00	1,201.73
Printing and Blueprinting	0.00	26.51
Stationery and Office Supplies	0.00	5.48
Postage	0.00	21.36
Total Real Estate	$776.89	$154,750.52
WARE WATERSHED PROTECTION:		
Salaries, Engineering and Clerical	$11,562.33	$112,165.79
Legal and Expert Expense	1,525.59	16,238.13
Consultant Expense	0.00	763.70
Labor	264.00	9,522.24
Engineering Instruments	27.89	317.14
Completed Contract No. 27	0.00	4,395.51
Contract No. 39, Rutland-Holden Sewer	46,184.76	238,708.67
Automobile Purchase	24.50	568.45
Automobile Maintenance	536.83	3,702.73
Special Experiments	0.00	700.00
Miscellaneous Expense (undistributed)	373.41	4,699.01
Advertising	2.00	2.00
Printing and Blueprinting	12.14	470.21
Stationery and Office Supplies	5.60	97.94
Postage	16.85	16.85
Installed Equipment	158.19	5,610.75
Purchases and Settlements	26,499.70	1,082,745.19
Taxes	8,659.00	28,085.41
Maintenance of Real Estate	1,577.41	1,753.82
Special Agents, Salaries	2,460.00	4,728.67
Rent and Upkeep	48.86	48.86
Automobile Purchase	303.35	303.35
Automobile Maintenance	456.56	966.24
Miscellaneous Expense (undistributed)	291.60	549.51
Printing and Blueprinting	3.19	3.19
Stationery and Office Supplies	0.76	1.91
Postage	7.50	13.50
Rutland-Holden Sewer, Maintaining, Cleaning and Repairing		
State Sanatorium Branch	337.50	349.61
U. S. Vet. Hospital Branch	349.91	367.63
Trunk Sewer, except Branches	816.90	833.58
Total Ware Watershed Protection	$102,506.33	$1,518,729.59
WARE DIVERSION DAMAGES — EXCEPT JURY TRIAL:		
*Salaries, Engineering and Clerical	$-2,488.38	$82,160.39
Legal and Expert Expense	72.50	3,171.83
*Consultant Expense	-3,870.14	23,988.45
Labor	31.45	2,310.69
Furniture and Fixtures	0.25	24.41
Laboratory Equipment	36.21	186.35
Laboratory Supplies	77.23	286.94
Engineering Instruments	46.00	557.94
Rental of Equipment	0.00	203.75

* Expenditures previously carried in these accounts and applying to cases assigned for trial during the year have been transferred to corresponding Jury Trial accounts.

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Rent and Upkeep	$0.13	$0.13
Automobile Purchase	25.04	170.42
Automobile Maintenance	390.46	3,425.39
Contracts for Investigations and Surveys	0.00	63.27
Materials of Construction	0.00	136.51
Miscellaneous Expense (undistributed)	292.75	7,255.68
Printing and Blueprinting	154.52	1,232.34
Stationery and Office Supplies	34.84	59.12
Postage	0.00	6.62
Purchases and Settlements	1,300.00	166,525.00
Sub Total Ware Diversion Damages — Except Jury Trial	$-3,897.14	$291,765.23
WARE DIVERSION DAMAGES — JURY TRIAL:		
Salaries, Engineering and Clerical	$28,297.91	$41,524.60
Legal Expense	5,041.34	16,117.47
Consultant Expense	20,762.96	35,985.52
Expert and other Witness Expense	0.00	10,541.97
Automobile Maintenance	27.75	72.11
Miscellaneous Expense (undistributed)	706.94	2,396.74
Printing and Blueprinting	248.19	248.19
Settlements	0.00	260,000.00
Payments under Certificates of Judgment	190,208.95	190,208.95
Sub Total Ware Diversion Damages — Jury Trial	$245,294.04	$557,095.55
Total Ware Diversion Damages	241,396.90	848,860.78
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:	$0.00	$9,629,739.99
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$59,018.10
Temporary Equipment	0.00	6,423.60
Labor	427.20	4,060.44
Contracts for Equipment for Surveys	0.00	898.34
Maintenance of Partially Completed Structures	1,520.65	8,966.24
Maintenance of Grounds	852.57	3,638.86
Purchase of Plants, Trees and Shrubbery	0.00	842.58
Rental of Equipment	0.00	7.00
Miscellaneous Expense	0.00	9,453.84
Total	$2,800.42	$93,309.00
Total Wachusett-Coldbrook Tunnel, Ware Supply	$364,872.62	$13,116,946.91
SPECIAL INVESTIGATION — POLLUTION OF WARE AND QUINAPOXET WATERSHEDS (Expenditures under Chapter 66, Resolves of 1931)		
Total Special Investigation	$0.00	$1,995.99
WACHUSETT WATERSHED PROTECTION		
ENGINEERING:		
Salaries, Engineering and Clerical	$2,138.57	$2,138.57
Legal Expense	3.55	3.55
Labor	27.20	27.20

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Automobile Maintenance	$47.33	$47.33
Miscellaneous Expense (undistributed)	216.03	216.03
Printing and Blueprinting	6.50	6.50
Total Wachusett Watershed Protection	$2,439.18	$2,439.18

COLDBROOK-SWIFT TUNNEL SECTION OF QUABBIN AQUEDUCT

GENERAL OVERHEAD:		
Administration	$6,135.66	$27,961.78
Engineering	20,834.70	108,043.44
Total General Overhead	$26,970.36	$136,005.22
ENGINEERING:		
Salaries, Engineering and Clerical	$37,530.81	$250,306.75
Consultant Expense	78.63	412.75
Labor	276.00	812.25
Furniture and Fixtures	250.00	1,020.91
Engineering Instruments	13.59	4,551.29
Rent and Upkeep	1,242.02	10,268.98
**Rental of Equipment	0.00	3.00
Automobile Purchase	–125.00	8,010.52
Automobile Maintenance	1,841.10	17,326.49
Contracts for Investigations and Surveys	0.00	13,525.66
Materials of Construction	0.00	2.25
Miscellaneous Expense (undistributed)	310.52	7,644.99
Printing and Blueprinting	98.84	909.57
Stationery and Office Supplies	96.75	2,095.54
Postage	60.73	505.29
Total Engineering	$41,673.99	$317,396.24
REAL ESTATE:		
Legal and Expert Expense	$15.27	$3,099.64
Labor	0.00	12.20
Miscellaneous Expense (undistributed)	0.00	27.16
Printing and Blueprinting	0.00	34.87
Postage	0.00	5.68
Purchases and Settlements	0.00	22,585.00
Taxes	257.48	724.77
Maintenance of Real Estate	0.00	24.85
Fire Protection, Equipment	0.00	60.86
Total Real Estate	$272.75	$26,575.03
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 20, Construction of Coldbrook-Swift Tunnel	$365,790.78	$4,809,852.83
Total Contracts	$365,790.78	$4,809,852.83
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$244.20	$308.95
Installed Equipment	371.70	489.34
**Water Supply System	3,203.04	3,222.24
Miscellaneous Expense	148.47	2,487.43
Total	$3,967.41	$6,507.96
Total Coldbrook-Swift Tunnel	$438,675.29	$5,296,337.28

** This expenditure was previously carried under Miscellaneous Expense.

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Quabbin Reservoir Except Main Dam and Dike		
General Overhead:		
Administration	$10,309.56	$95,450.20
Engineering	36,392.20	496,715.55
Total General Overhead	$46,701.76	$592,165.75
Engineering:		
Salaries, Engineering and Clerical	$53,425.52	$366,343.26
Consultant Expense	0.00	228.23
Labor	3,765.45	10,984.14
Furniture and Fixtures	49.85	3,066.88
Laboratory Equipment	367.93	1,378.24
Laboratory Supplies	792.37	2,727.72
Rental of Equipment	0.00	16.75
Engineering Instruments	–57.82	6,344.46
Rent and Upkeep	1,249.62	8,295.65
Automobile Purchase	2,129.46	17,165.85
Automobile Maintenance	2,144.31	15,273.96
Special Experiments	0.00	422.80
Contracts for Investigations and Surveys	678.09	12,746.63
Office Buildings	137.62	5,053.16
Miscellaneous Expense (undistributed)	882.31	5,620.71
Printing and Blueprinting	316.19	2,052.87
Stationery and Office Supplies	578.91	5,531.87
Postage	186.50	1,091.64
Total Engineering	$66,646.31	$464,344.82
Real Estate — Except Board of Referees and Jury Trial:		
Legal and Expert Expense	$9,279.14	$152,968.37
Consultant Expense	146.78	146.78
Labor	245.80	341.15
Furniture and Fixtures	0.00	15.68
Automobile Maintenance	14.42	14.42
Miscellaneous Expense (undistributed)	1,494.39	7,045.66
Advertising	0.00	208.66
Printing and Blueprinting	29.66	1,316.46
Stationery and Office Supplies	0.00	0.45
Purchases and Settlements	279,462.56	6,176,998.52
Purchase, part of Athol Branch, Boston & Albany Railroad	*575,000.00	*575,000.00
Taxes	67,906.89	291,468.58
Maintenance of Real Estate	2,256.20	6,536.93
Water Supply System	0.00	40.60
Fire Protection, Labor	383.50	410.70
Tools and Equipment	1,237.47	4,790.30
Automobile Purchase	0.00	771.69
Automobile Maintenance	23.19	280.33
Miscellaneous Expense	41.29	171.02
Police Protection, Labor	0.00	14.00
Special Agents, Salaries	2,460.00	18,026.00
Equipment	0.00	118.33
Automobile Purchase	303.35	1,540.31
Automobile Maintenance	335.51	3,053.30
Miscellaneous Expense (undistributed)	157.60	1,247.03
Printing and Blueprinting	11.12	52.72
Stationery and Office Supplies	1.08	10.41

* This entry made by order of the Comptroller of the Commonwealth.

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Postage	$3.45	$17.07
Renting Agents, Salaries	2,820.00	20,888.10
Legal Expense	60.00	60.00
Furniture and Fixtures	0.00	29.29
Miscellaneous Expense (undistributed)	125.07	611.03
Printing and Blueprinting	0.00	18.62
Stationery and Office Supplies	1.75	35.16
Postage	14.71	129.59
Payments to Towns	2,000.00	14,500.00
Sub Total Real Estate — Except Board of Referees and Jury Trial	$945,814.93	$7,278,877.26
REAL ESTATE — BOARD OF REFEREES:		
Salaries of Referees	$0.00	$6,940.00
Salaries, Engineering and Clerical	0.00	967.88
Legal Expense	698.57	4,823.53
Consultant Expense	0.00	622.40
Expert and other Witness Expense	0.00	4,510.07
Expenses of Board of Referees	0.00	550.30
Miscellaneous Expense	0.00	45.78
Sub Total Real Estate — Board of Referees	$698.57	$18,459.96
REAL ESTATE — JURY TRIAL:		
Salaries, Engineering and Clerical	$0.00	$27.73
Legal Expense	301.85	471.18
Miscellaneous Expense	2.00	2.00
Payments under Certificates of Judgment	7,751.87	7,751.87
Sub Total Real Estate — Jury Trial	$8,055.72	$8,252.78
Total Real Estate	$954,569.22	$7,305,590.00
QUABBIN RESERVOIR DAMAGES:		
Salaries, Engineering	$0.00	$48.68
Legal and Expert Expense	0.00	931.00
Consultant Expense	0.00	2,158.82
Miscellaneous Expense	0.00	18.15
Purchases and Settlements	265.00	45,675.00
Total Quabbin Reservoir Damages	$265.00	$48,831.65
SWIFT DIVERSION DAMAGES:		
Salaries, Engineering and Clerical	$2,644.23	$68,402.31
Legal and Expert Expense	63.69	5,646.52
Consultant Expense	8,490.83	69,854.17
Labor	283.05	421.19
Furniture and Fixtures	2.21	39.72
Laboratory Equipment	325.74	1,292.56
Laboratory Supplies	694.19	2,347.72
Engineering Instruments	0.84	741.45
Rent and Upkeep	1.15	1.15
Rental of Equipment	0.00	10.50
Automobile Purchase	225.31	1,533.72
Automobile Maintenance	1,019.10	3,154.02
Contracts for Investigations and Surveys	0.00	569.47
Materials of Construction	0.00	18.99
Miscellaneous Expense (undistributed)	119.50	6,057.37
Printing and Blueprinting	85.44	973.25

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Stationery and Office Supplies	$13.12	$41.01
Purchases and Settlements	0.00	942,975.00
Total Swift Diversion Damages	$13,968.40	$1,104,080.12
Quabbin Reservoir — Cemeteries		
Quabbin Park Cemetery Construction:		
Salaries, Engineering and Clerical	$420.00	$11,564.27
Legal and Expert Expense	0.00	65.00
Consultant Expense	0.00	125.00
(Construction) Labor	2,422.40	13,409.75
Tools and Equipment	10.03	93.99
Automobile Purchase	0.00	1,615.37
Automobile Maintenance	208.43	1,275.18
Rental of Equipment	0.00	33.19
Purchases and Settlements	0.00	8,850.00
Construction Materials	90.55	1,644.76
Purchase and Planting of Trees and Shrubbery	0.00	218.93
Receiving Vault	0.00	2,768.85
Water Supply System	0.00	1,251.97
Maintenance of Grounds	1,440.03	4,756.29
Miscellaneous Expense (undistributed)	18.79	175.65
Printing and Blueprinting	0.00	159.08
Stationery and Office Supplies	1.02	10.05
Completed Contract No. 34	0.00	7,842.94
Sub Total Quabbin Park Cemetery Construction	$4,611.25	$55,860.27
Removals from Cemeteries within Reservoir Area to Quabbin Park Cemetery:		
Salaries, Engineering and Clerical	$2,210.50	$6,939.09
Tools and Equipment	26.24	438.38
Automobile Purchase	0.00	2,669.99
Automobile Maintenance	316.68	1,099.89
Removal and Reinterment of Bodies	2,949.25	10,188.53
Removal and Resetting of Monuments	1,776.96	6,722.98
Miscellaneous Expense	0.00	2.00
Rental of Equipment	0.00	10.50
Sub Total Removals to Quabbin Park Cemetery	$7,279.63	$28,071.36
Removals from Cemeteries within Reservoir Area to Cemeteries other than Quabbin Park:		
Salaries, Engineering and Clerical	$140.75	$5,856.49
Automobile Purchase	0.00	380.00
Automobile Maintenance	27.97	90.06
Purchases and Settlements	196.00	6,959.10
Perpetual Care Fund Contributions	0.00	175.00
Removal and Reinterment of Bodies	377.50	6,467.45
Removal and Resetting of Monuments	219.60	5,717.34
Miscellaneous Expense	5.60	123.51
Sub Total Removals to Other Cemeteries	$967.42	$25,768.95
Total Quabbin Reservoir Cemeteries	$12,858.30	$109,700.58

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Contract No. 49, Excavating Diversion Channels	$6,570.00	$6,570.00
Total Contracts	$6,570.00	$6,570.00
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Installed Equipment	$0.00	$214.78
Reservoir Clearing, Labor	571.00	571.00
Tools and Equipment	286.12	286.12
Automobile Maintenance	46.09	46.09
Miscellaneous Expense	3.05	3.05
Total	$906.26	$1,121.04
HIGHWAY AND PUBLIC UTILITY RELOCATION:		
Salaries, Engineering and Clerical	$20,280.31	$158,003.53
Legal and Expert Expense	0.00	49.10
Consultant Expense	4.60	8,454.75
Labor	2,355.20	6,008.41
Furniture and Fixtures	0.00	61.74
Completed Contracts Nos. 21 and 40	0.00	284,770.35
Contract No. 41, Construction of about 9.1 miles of the Belchertown-Pelham Highway in Belchertown and Pelham	23,810.83	130,091.17
Contract No. 43, Construction of about 7.6 miles of Extension of Belchertown-Pelham Highway in Shutesbury and New Salem to New Salem Center	118,871.15	275,259.52
Contract No. 44, Construction of about 4.1 miles of Extension of Belchertown-Pelham Highway in New Salem and Orange	$34,175.12	$136,717.39
Installed Equipment	0.00	811.57
Temporary Equipment	0.00	149.50
Engineering Instruments	0.00	625.14
Automobile Purchase	0.00	535.00
Automobile Maintenance	550.54	4,482.86
Miscellaneous Expense (undistributed)	896.99	4,639.93
Printing and Blueprinting	2.96	292.49
Stationery and Office Supplies	0.00	90.34
Maintenance of Real Estate	551.60	551.60
Total Highway and Public Utility Relocation	$201,499.30	$1,011,594.39
QUABBIN RESERVOIR WATERSHED PROTECTION REFORESTATION:		
Nurseries; Salaries, Engineering	$144.15	$144.15
Labor	2,014.35	2,014.35
Tools and Equipment	62.06	62.06
Automobile Maintenance	35.98	35.98
Miscellaneous Expense	8.50	8.50
Watershed; Saleries, Engineering	280.76	280.76
Labor	5,490.90	5,490.90
Tools and Equipment	165.63	165.63
Automobile Maintenance	9.22	9.22
Miscellaneous Expense	61.01	61.01
Sub Total Reforestation	$8,272.56	$8,272.56
Total Quabbin Reservoir Watershed Protection	$8,272.56	$8,272.56
Total Quabbin Reservoir, Except Main Dam and Dike	$1,312,257.11	$10,652,270.91

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Quabbin Reservoir Main Dam		
General Overhead:		
Administration	$5,290.70	$23,675.89
Engineering	20,023.83	87,533.11
Total General Overhead	$25,314.53	$111,209.00
Engineering:		
Salaries, Engineering and Clerical	$42,484.24	$117,955.01
Consultant Expense	75.75	5,154.26
Labor	5,540.15	10,833.63
Furniture and Fixtures	66.76	130.94
Laboratory Equipment	9.73	453.77
Rental of Equipment	782.25	1,202.25
Engineering Instruments	214.93	416.49
Rent and Upkeep	383.16	703.24
Automobile Purchase	295.00	1,495.00
Automobile Maintenance	1,801.15	3,006.00
Contracts for Investigations and Surveys	6,391.71	58,620.92
Office Buildings	328.39	578.39
Special Experiments	32.40	1,600.89
Water Supply System	0.00	20.00
Miscellaneous Expense (undistributed)	892.05	11,425.48
Printing and Blueprinting	633.96	698.11
Stationery and Office Supplies	465.39	610.44
Postage	51.93	52.48
Total Engineering	$60,448.95	$214,957.30
Permanent Construction — Construction Contracts:		
Completed Contracts Nos. 30 and 32	$0.00	$593,001.41
Contract No. 36, Constructing Exploratory Caissons at Main Dam	43,439.63	211,912.11
Contract No. 38, Constructing a Core Wall to Sound Rock at Main Dam	919,646.10	919,646.10
Total Contracts	$963,085.73	$1,724,559.62
Permanent Construction — Except Construction Contracts:		
Labor	$961.90	$3,453.70
Installed Equipment	0.00	3,253.00
Temporary Equipment	0.00	4,213.39
Miscellaneous Expense	9,802.35	12,098.50
Total	$10,764.25	$23,018.59
Total Quabbin Reservoir Main Dam	$1,059,613.46	$2,073,744.51
Quabbin Reservoir Beaver Brook Dike		
General Overhead:		
Administration	$3,953.19	$24,700.38
Engineering	14,050.47	92,884.89
Total General Overhead	$18,003.66	$117,585.27
Engineering:		
Salaries, Engineering and Clerical	$33,798.97	$100,877.96
Consultant Expense	116.87	4,940.84
Labor	3,260.32	8,186.24
Furniture and Fixtures	0.00	127.22
Laboratory Equipment	0.00	315.73

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Rental of Equipment	$0.00	$921.50
Engineering Instruments	64.62	116.89
Rent and Upkeep	0.00	16.00
Automobile Purchase	0.00	600.00
Automobile Maintenance	566.85	1,853.67
Contracts for Investigations and Surveys	471.26	24,080.73
Special Experiments	1.60	55.20
Miscellaneous Expense	194.95	4,760.56
Printing and Blueprinting	7.52	1,278.75
Stationery and Office Supplies	95.80	158.99
Advertising	0.00	79.34
Total Engineering	$38,578.76	$148,369.62
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS:		
Completed Contract No. 32	$0.00	$114,447.52
Contract No. 36, Constructing a Core Wall to Sound Rock at Dike	115,001.02	939,690.38
Contract No. 50, Constructing the Embankment of the Dike	360,578.70	360,578.70
Total Contracts	$475,579.72	$1,414,716.60
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS:		
Labor	$333.30	$9,757.25
Temporary Equipment	1,687.53	1,993.18
Tools and Equipment	0.00	14.70
Miscellaneous Expense	86.49	1,648.53
Total	$2,107.32	$13,413.66
Total Quabbin Reservoir Beaver Brook Dike	$534,269.46	$1,694,085.15

SOUTHERN SUDBURY EMERGENCY SUPPLY

GENERAL OVERHEAD	$0.00	$42,098.25
ENGINEERING	0.00	44,235.07
REAL ESTATE	0.00	30,553.18
SOUTHERN SUDBURY DIVERSION DAMAGES	0.00	50,752.66
PERMANENT CONSTRUCTION — CONSTRUCTION CONTRACTS	0.00	458,957.30
PERMANENT CONSTRUCTION — EXCEPT CONSTRUCTION CONTRACTS	0.00	11,937.37
Total Southern Sudbury Emergency Supply	$0.00	$638,533.83

SUMMARY

Wachusett-Coldbrook Tunnel, Ware Supply	$364,872.62	$13,116,946.91
Special Investigation — Pollution of Ware and Quinapoxet Watersheds	0.00	1,995.99
Wachusett Watershed Protection	2,439.18	2,439.18
Coldbrook-Swift Tunnel	438,675.29	5,296,337.28
Quabbin Reservoir except Main Dam and Dike	1,312,257.11	10,652,270.91
Quabbin Reservoir Main Dam	1,059,613.46	2,073,744.51
Quabbin Reservoir Beaver Brook Dike	534,269.46	1,694,085.15
Southern Sudbury Emergency Supply	0.00	638,533.83
Unassigned	393.54	956.96
Grand total	$3,712,520.66	$33,477,310.72

	Year ending Nov. 30, 1935	Total to Nov. 30, 1935
Receipts from Rents, Sales, etc.		
Sales	$49,890.99	$182,922.01
Rents	47,574.12	351,875.35
Miscellaneous	97,355.70	102,631.73
Total Receipts	$194,820.81	$637,429.09

COMMONWEALTH OF MASSACHUSETTS

METR. DISTR. WATER SUPPLY COMMISSION

LOCATION OF REAL ESTATE ACQUIRED FOR THE QUABBIN RESERVOIR

(TITLE VESTED IN COMMONWEALTH)

TOWNS	TOTAL - NOV. 30, 1934. 1934 ANNUAL REPORT (ACRES)	TOTAL - NOV. 30, 1934. REVISED - SEE NOTE (ACRES) *	TOTAL FOR YEAR ENDING NOV. 30, 1935 (ACRES)	TOTAL NOV. 30, 1935 (ACRES)	REMARKS
BELCHERTOWN	2,803	2,804	68	2,872	* Revisions have been made using acreages obtained from surveys wherever available, otherwise from deeds, property blanks, etc.
DANA	8,236	8,236	294	8,530	
ENFIELD	7,831	7,830	808	8,638	
GREENWICH	10,475	10,476	121	10,597	
HARDWICK	2,975	2,974	59	3,033	
NEW SALEM	7,983	7,995	1,591	9,586	
ORANGE	1	1	20	21	
PELHAM	4,567	4,567	153	4,720	
PETERSHAM	719	720	85	805	
PRESCOTT	10,227	10,227	280	10,507	
SHUTESBURY	2,625	2,623	483	3,106	
WARE	722	713	116	829	
WENDELL	36	37	223	260	
TOTALS	59,200	59,203	4,301	63,504	

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LOCATION OF REAL ESTATE ACQUIRED FOR THE QUABBIN RESERVOIR

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COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

TAKINGS OF REAL ESTATE (AND WATER RIGHTS)

TAKING FOR	TAKING NO.	TOWN	COUNTY	DATE OF TAKING	PLAN NO.	TITLE VESTED IN COMMONWEALTH FEE (Acres)	TITLE VESTED IN COMMONWEALTH EASEMENT (Acres)
Southern Sudbury Emergency Supply.	1 to 9 incl.	Details previously reported in the 1930 Annual Report.			C-1 to C-15 incl.	258.81 (Also Water Rights)	29.02
Wachusett-Coldbrook Tunnel section of Quabbin Aqueduct.	1 to 4 incl.	Details previously reported in the 1930 Annual Report.			T-1 to T-13 incl.	570.22	20.37
Coldbrook-Swift Tunnel section of Quabbin Aqueduct.	1 to 3 incl.	Details previously reported in the 1931 Annual Report. *(391.42 acres of this total are within the Quabbin Reservoir Area)			T-14 to T-27 incl.	*544.81	4.06
Quabbin Reservoir.	1 to 13 incl.	Details previously reported in the 1931, 1932, 1933 and 1934 Annual Reports.			S-1 to S-28 incl.	637.01	19.85
" " (Taking of Waters of Beaver Brook above Dike of Quabbin Reservoir.)	—	Enfield	Hampshire	Mar. 22, 1935.	None	Water Rights	
Ware River Supply and Watershed.	1 to 2 incl.	Details previously reported in the 1932 and 1933 Annual Reports.			W-1 and A-1 to A-14 incl.	0.25	22.94
	—	Details previously reported in the 1931 Annual Report.			None	Water Rights	

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

STATUS OF CONTRACTS COMPLETED BETWEEN NOV. 30, 1934 AND NOV. 30, 1935

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	FINAL ESTIMATE	DATE OF FINAL EST.
20	Coldbrook-Swift Tunnel.	Barre, Hardwick and Greenwich	Swift	Wenzel & Henoch, Construction Co.	Mar. 27, 1931	13	April 10, 1931	$4,978,031.80	$4,809,852.83	Oct. 1, 1935
23	Making Borings.	Belchertown, Ware, Enfield, Greenwich & Hardwick	Swift	Sprague & Henwood, Inc.	Nov. 5, 1929	6	Nov. 5, 1929	10,950.00	59,044.29	Sept. 11, 1935
35	Purchase of Power at Dam Site.	Enfield	Swift	New England Power Co.	Date of Agreement = June 2, 1932			Agreed Rates	19,367.18	June 1, 1935
36	Core Wall to Bed Rock at Dike Site.	Enfield & Ware	Swift	West Construction Co.	Dec. 9, 1932	25	Dec. 28, 1932	999,265.00	1,151,602.49	Dec. 22, 1934
39	Construction of Trunk Sewer.	Rutland & Holden	Ware	James J. Coughlan & Sons, Inc.	July 7, 1933	21	July 11, 1933	184,327.50	238,708.67	June 4, 1935
41	Construction of Portion of Belchertown-Pelham Highway.	Belchertown & Pelham	Swift	Carlo Bianchi & Company, Inc.	July 18, 1933	14	July 19, 1933	222,335.50	248,578.14 **	Nov. 20, 1934
44	Construction of Extension of Belchertown-Pelham Highway. North of New Salem Center.	New Salem & Orange	Swift	John Iafolla Construction Co.	Nov. 10, 1933	9	Nov. 14, 1933	179,480.50	199,940.12 **	Nov. 20, 1934

STATUS OF CONTRACTS IN FORCE ON NOV. 30, 1935

CONT. NO.	DESCRIPTION	LOCATION	SUPPLY	CONTRACTOR	BIDS OPENED	NO. OF BIDS	CONTRACT AWARDED	BASIS OF AWARD	PAYMENTS TO DATE
33	Purchase of Power at Shaft 1.	West Boylston	Ware	New England Power Co.	Date of Agreement = Aug. 6, 1931.			Agreed Rates	$ 1,923.63
38	Core Wall to Bed Rock at Dam Site.	Belchertown, Enfield & Ware	Swift	The Two Companies, Inc.	May 7, 1935	9	May 9, 1935.	$1,330,765.00	1,021,829.00
42	Use of Worcester Sewerage System and Treatment Works % Rutland-Holden Sewer.	Worcester	Ware	City of Worcester	Date of Agreement = May 1, 1933			Lump Sum = 325,000.00 Annual Charge = *	325,000.00 None
43	Construction of Extension of Belchertown-Pelham Highway to New Salem Center.	Shutesbury & New Salem	Swift	V. Barletta Co.	Aug. 11, 1933	7	Aug. 22, 1933	300,397.50	376,964.65 **
46	Connection with Rutland-Holden Sewer, & Disposal of Sewage from the U.S. Veterans Hospital.	Rutland (Note:-Payments under Contract 46 are RECEIVED by the M.D.W.S.C.)	Ware	U.S. Veterans Administration.	Date of Agreement = Nov. 7, 1934			Lump Sum = 37,000.00 Annual Charge = *	37,000.00 None
48	Connection with Rutland-Holden Sewer, & Disposal of Sewage from the Rutland State Sanatorium.	Rutland (Note:-Payments under Contract 48 are RECEIVED by the M.D.W.S.C.)	Ware	Rutland State Sanatorium.	Date of Agreement = June 5, 1934			Lump Sum = 60,000.00 Contingent Charge = *	60,000.00 None
49	Excavating Diversion Channels at the Site of Quabbin Reservoir.	Dana, Hardwick & Greenwich.	Swift	Cenedella & Co.	Sept. 10, 1935	12	Oct. 1, 1935	79,050.00	7,300.00
50	Dike Embankment - Quabbin Reservoir.	Enfield & Ware	Swift	The Arthur A. Johnson Corporation	Nov. 13. 1934	6	Nov. 26, 1934	1,446,655.00	400,643.00

* Proportion of Annual Maintenance Cost.
** Of these amounts the State Dept. of Public Works has paid $118,486.97 on Cont. 41, $101,705.13 on Cont. 43 and $63,222.73 on Cont. 44, covering the surfacing, guard rail and traffic signal duct items.

The above contracts were all awarded to the lowest bidder except Contract 43 which was awarded to the 2nd lowest bidder.

Commonwealth of Massachusetts
METR. DISTR. WATER SUPPLY COMMISSION

CANVASS OF BIDS FOR CONTRACT 38
OPENED MAY 7, 1935

FOR CONSTRUCTING A CORE WALL TO SOUND ROCK AT THE SITE OF THE MAIN DAM OF QUABBIN RESERVOIR IN THE TOWNS OF BELCHERTOWN, ENFIELD AND WARE

				* (1) The Two Companies C.J Maney Company, Inc 50 Congress St Boston, Mass B Perini & Sons, Inc. Framingham, Mass.		(2) The Dominion Construction Company, Inc. % James J. Coughlan & Sons, Inc 80 Federal St Boston, Mass		(3) Cornell Contracting Corporation 405 Lexington Ave. New York, N. Y.		(4) West Construction Company 60 State St. Boston, Mass.		(5) Rodgers & Hagerty Inc. 500 5th Avenue New York, N. Y.		(6) Underpinning & Foundation Co. Inc. 155 East 44th St. New York, N. Y.		(7) The Dravo Contracting Company Wille Island Sta Pittsburgh, Pa		(8) The Arthur F. Johnson Corporation Enfield, Mass.		(9) Peter F. Connolly Company 29-28 41st Avenue Long Island City, N. Y.	
Item	Description	Unit	Quantity	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1	Clearing and grubbing	Acre	25	75.00	$ 1,875.00	90.00	$ 2,250.00	250.00	$ 6,250.00	102.00	$ 2,550.00	230.00	$ 5,750.00	100.00	$ 2,500.00	100.00	$ 2,500.00	75.00	$ 1,875.00	210.00	$ 5,250.00
2	Earth excavation in open cut	Cu. Yd.	230,000	.65	149,500.	.26	59,800.	.23	52,900	.24	55,200.	.35	80,500.	.60	138,000	.20	46,000.	.40	92,000.	.40	92,000.
3	Rock excavation as boulders in open cut	Cu Yd	7,000	.65	4,550.	.55	3,850	.23	1,610	.65	4,550	.35	2,450.	1	7,000.	.60	4,200.	2	14,000	2.50	17,500.
4	Rock excavation as ledge in open cut	Cu Yd	6,000	7.50	45,000.	.6	36,000	3.50	21,000.	.5	30,000.	.8	48,000	.3	18,000.	.6	36,000	2.50	15,000	.4	24,000.
5	Stripping	Cu Yd	60,000	.65	39,000	.28	16,800	.40	24,000.	.27	16,200.	.35	21,000.	.70	42,000.	.25	15,000	.64	38,400	.40	24,000.
6	Unconsolidated embankment	Cu. Yd	40,000	.05	2,000.	.15	6,000.	.10	4,000	.11	4,400.	.10	4,000.	.20	8,000.	.10	4,000.	.40	16,000	.30	12,000
7	Consolidated pervious embankment	Cu Yd	190,000	.05	9,500.	.09	17,100	.12	22,800.	.11	20,900	.15	28,500	.30	57,000.	.11	20,900.	.46	87,400.	.50	95,000
8	Rolled impervious embankment in core	Cu Yd	90,000	.60	54,000	.60	54,000.	.40	36,000	.63	56,700	.45	40,500	.30	27,000.	.60	54,000.	.50	45,000	.40	36,000.
9	Rolled impervious embankment not in core	Cu Yd	40,000	.60	24,000.	.60	24,000	.35	14,000	.63	25,200	.60	24,000.	.30	12,000	.60	24,000.	.50	20,000.	.40	16,000
10	Stone fills	Cu Yd.	65,000	1.00	65,000.	.77	50,050.	.40	26,000.	.81	52,650	.90	58,500	.90	58,500.	.70	45,500.	.50	32,500	1.	65,000
11	Pumping (Unit price fixed)	Mil ft.-gals.	300,000	10	30,000.	10	30,000	10	30,000.	10	30,000	10	30,000	10	30,000.	10	30,000.	10	30,000.	10	30,000
12	Control of surface waters	Lump Sum		4,600	4,600.	10,000	10,000	20,000	20,000	7,200	7,200	8,000.	8,000.	2,000	2,000.	6,000.	6,000.	6,000.	6,000	10,000.	10,000
13	Earth excav core wall, bottom open cut to Elev 300	Cu Yd	35,000	.7	245,000.	.7.	245,000.	.12	420,000.	6.15	215,250	10.	350,000.	.8	280,000.	6.50	227,500.	12.50	437,500.	11.30	398,300
14	Earth excavation for core walls, below Elev 300	Cu Yd	5,000	.7.	35,000.	15.10	75,500.	.12	60,000.	18.63	93,150.	.10.	50,000	.10.	50,000.	.9	45,000	12.50	62,500.	.21	105,000
15	Rock excavation in caissons above Elev. 300	Cu. Yd.	3,000	11.	33,000.	9.50	28,500.	.12	36,000.	19.22	57,660	20.	60,000.	.8	24,000.	11	33,000.	20.25	60,750	.12	36,000.
16	Rock excavation in caissons below Elev. 300	Cu. Yd	1,000	11	11,000	20	20,000	20.	20,000.	30.26	30,260	20	20,000	.8	8,000.	11	11,000.	20.25	20,250	.21	21,000.
17	Rock excav. core wall, below open cut, outside caisson limits	Cu Yd	300	10	3,000	10	3,000	12.	3,600.	6.46	1,944.	9	2,700.	.8	2,400	12	3,600.	2.55	765	12.50	3,750
18	Preparing rock surface in caissons above Elev 300	Sq. Yd	1,100	2	2,200	9	9,900.	3	3,300.	9.37	10,307	2.50	2,750.	.8	8,800.	3	3,300.	9	9,900.	5	5,500.
19	Preparing rock surface in caissons below Elev 300	Sq Yd.	650	2.	1,300.	9	5,850.	3.	1,950	14.20	9,230.	2.50	1,625.	.8	5,200.	4	2,600.	9	5,850.	5	3,250.
20	Preparing rock surface outside caisson limits	Sq Yd	600	2	1,200.	4	2,400.	3	1,800	3.20	1,920.	2.50	1,500.	.8	4,800.	.6	3,600.	4.85	2,910.	5	3,000
21	Concrete, not placed under air pressure	Cu. Yd	50,000	.6	300,000	7.40	370,000	.6	300,000.	7.68	384,000	.8	400,000.	.8	400,000	13	650,000.	7.50	375,000.	.8	400,000
22	Concrete, placed under air pressure	Cu Yd	7,000	.6	42,000	6.70	46,900	.6.	42,000.	.7	49,000	.6	42,000	.8	56,000	15	105,000.	9.50	66,500.	.6.	56,000.
23	Impervious filling in caissons	Cu Yd	5,000	.1	5,000	1.08	5,400	.70	3,500	1.32	6,600	.70	3,500.	.7.	35,000.	1.50	7,500.	.62	3,100.	1.50	7,500
24	Imper fill. core wall, below open cut, outside caisson limits	Cu Yd	300	.1	300.	.68	204	.70	210	.85	255.	.70	210.	.7.	2,100	.3	900.	.62	186	1.50	450
25	Drilling holes in rock or masonry	Lin ft.	12,000	.80	9,600	1.40	16,800	1	12,000.	2.63	31,560.	1	12,000.	2	24,000	1	12,000.	.60	7,200.	1.25	15,000.
26	Furnishing and placing grout	Cu Yd.	1,000	11	11,000	15.	15,000	8	8,000	7.76	7,760	16	16,000	15	15,000	15	15,000	6.25	6,250	12	12,000
27	Portland cement	Barrel	90,000	2.20	198,000	2.70	243,000	3.	270,000	3.03	272,700	2.90	261,000	3	270,000	2.30	207,000.	2.65	238,500	2.75	247,500.
28	Maintenance of Highway	Lump Sum		2,000	2,000	2,500	2,500	10,000.	10,000	5,600.00	5,600	3,500.	3,500	3,000	3,000.	2,500	2,500.	1,750.	1,750.	3,000	3,000.
29	Maintenance of Engineer's office	Month	19	60	1,140.	200.	3,800	250	4,750.	150.00	2,850	200.	3,800	200.	3,800	200.	3,800	135	2,565	3,800.	72,200.
30	Cleaning up	Lump Sum		1,000.	1,000.	2,500.	2,500	6,000	6,000.	2,000.	2,000.	1,000.	1,000	2,000.	2,000.	2,000.	2,000.	2,500.	2,500.	2,000.	2,000
			Totals		$1,330,765.00		$1,406,104.00		$1,461,670.00		$1,487,616.00		$1,582,705.00		$1,596,100.00		$1,623,400.00		$1,702,151.00		$1,818,200.00

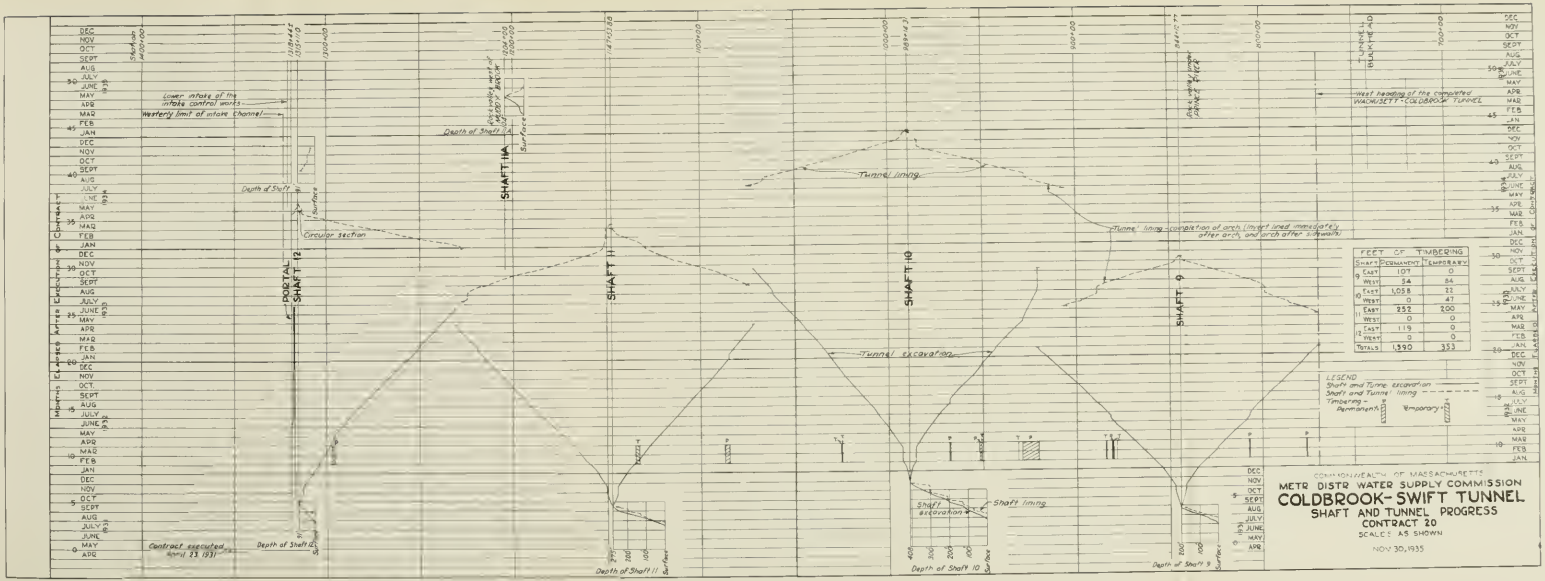
*Contract awarded May 9, 1935
Contract executed May 15, 1935

Canvass of Bids for Contract 49, Opened Sept. 10, 1935

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
CONTRACT 49
For Excavating Diversion Channels at the Site of Quabbin Reservoir in the Towns of Dana, Hardwick, and Greenwich

Item	Description of Item	Unit	Quantity	1 Ceneoella & Co ★ 167 Main St, Milford, Mass		2 Edward J. Byrne 89 State St, Boston, Mass.		3 V Barletta Co 8 Whipple Ave, Roslindale, Mass		4 Carlo Bianchi & Company, Inc. Framingham, Mass		5 Kelleher Corporation Turners Falls, Mass		6 Ralph D. Marois 18 Arthur St, Worcester, Mass		7 John Iafolla Construction Co. 11 Van Brunt Ave Dedham, Mass		8 S. J. Groves and Sons Co 509 Wesley Temple Bldg, Minneapolis Minn		9 Peter Salvucci 55 Pond St, Waltham, Mass		10 H E Cline Construction Co. 1 Beacon St, Boston, Mass		11 J H Ferguson Co. 289 Chapman St, Providence, R I.		12 The Two Companies Inc Enfield, Mass	
				Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount	Price	Amount
1	Clearing	Acre	100	50.00	5,000.00	100.00	10,000.00	95.00	9,500.00	70.00	7,000.00	125.00	12,500.00	150.00	15,000.00	200.00	20,000.00	150.00	15,000.00	100.00	10,000.00	200.00	20,000.00	150.00	15,000.00	150.00	15,000.00
2	Grubbing	Acre	50	50.00	2,500	100.00	5,000	350.00	17,500	200.00	10,000	450.00	22,500	150.00	7,500	400.00	20,000	250.00	12,500	300.00	15,000	50.00	2,500	200.00	10,000	150.00	7,500
3	Earth excavation in channel between middle and east branches	Cu. Yd	220,000	.26	57,200	.27	59,400	.23	50,600	.25	55,000	.22	48,400	.25	55,000	.24	52,800	.30	66,000	.35	77,000	.35	77,000	.39	85,800	.70	154,000
4	Earth excavation in channel at Shaft 11-A	Cu Yd	4,500	1.00	4,500	.80	3,600	.50	2,250	1.20	5,400	1.25	5,625	.80	3,600	1.00	4,500	1.75	7,875	1.00	4,500	1.00	4,500	1.20	5,400	.95	4,275
5	Earth excavation in channel at Shaft 12	Cu Yd	13,000	.26	3,380	.79	10,270	.35	4,550	.50	6,500	.30	3,900	1.00	13,000	.50	6,500	.55	7,150	.50	6,500	.80	10,400	.60	7,800	.90	11,700
6	Excavation of boulders	Cu Yd	10,000	.01	100	.01	100	.75	7,500	.75	7,500	.60	6,000	.60	6,000	.24	2,400	1.00	10,000	1.00	10,000	2.00	20,000	2.00	20,000	.70	7,000
7	Grading banks of lower intake channel at Shaft 12	Cu Yd	500	1.00	500	1.00	500	.75	375	1.00	500	1.00	500	1.00	500	.50	250	1.00	500	.30	150	.80	400	1.50	750	1.50	750
8	Gravel road surfacing	Cu Yd	1,600	.65	1,040	.40	640	.50	800	.75	1,200	.80	1,280	.75	1,200	.50	800	1.25	2,000	.50	800	3.00	4,800	1.80	2,880	.65	1,040
9	Bituminous material	Gallon	1,200	.15	180	.15	180	.15	180	.25	300	.20	240	.20	240	.13	156	.50	600	.20	240	.15	180	.15	180	.15	180
10	Corrugated iron culvert pipe	Pound	2,000	.15	300	.11	220	.10	200	.15	300	.10	200	.20	400	.12	240	.12	240	.15	300	.15	300	.20	400	.13	260
11	Paving	Cu Yd	170	5.00	850	5.00	850	3.00	510	7.00	1,190	5.00	850	7.00	1,190	4.00	680	5.00	850	3.00	510	14.00	2,380	5.00	850	5.00	850
12	Wooden guard rail	Lin Ft	2,000	.55	1,100	.60	1,200	.35	700	.45	900	.60	1,200	.50	1,000	.35	700	.75	1,500	.60	1,200	1.50	3,000	.50	1,000	.65	1,300
13	Highway bridge	M Ft B M	30	80.00	2,400	125.00	3,750	100.00	3,000	100.00	3,000	100.00	3,000	85.00	2,550	70.00	2,100	1.00	3,000	100.00	3,000	150.00	4,500	100.00	3,000	110.00	3,300
			Totals ←		$73,050.00		$55,710.00		$97,665.00		$98,790.00		$106,195.00		$107,180.00		$111,126.00		$127,215.00		$129,200.00		$143,960.00		$153,060.00		$207,155.00

★ Contract awarded October 1, 1935
Contract executed October 2, 1935



FEET OF TIMBERING			
Shaft		Permanent	Temporary
9	East	107	0
	West	54	84
10	East	1,058	22
	West	0	47
11	East	252	200
	West	0	0
12	East	119	0
	West	0	0
Totals		1,390	353

COMMONWEALTH OF MASSACHUSETTS
METR DISTR WATER SUPPLY COMMISSION
COLDBROOK-SWIFT TUNNEL
SHAFT AND TUNNEL PROGRESS
CONTRACT 20
SCALES AS SHOWN
NOV 30, 1935

MONTHLY RAINFALL IN INCHES AT STATIONS ON THE WARE AND SWIFT WATERSHEDS, 1935

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
WARE WATERSHED													
Ware River Intake Works*	4.72	2.99	2.22	2.74	3.08	5.40	3.74	1.10	4.53	1.11	2.70	1.32	35.65
West Rutland*	5.14	3.22	2.61	2.93	3.29	5.73	3.85	1.25	4.55	1.21	3.55	1.41	38.74
North Rutland	7.54	4.22	2.09	3.85	2.80	7.08	3.63	.98	5.71	1.00	4.28	1.59	44.77
Williamsville	5.31	2.71	2.74	3.45	3.02	6.06	2.92	1.07	4.63	1.41	3.47	.87	37.66
Hubbardston	4.15	2.54	1.85	2.54	3.16	6.87	3.62	1.09	4.58	1.33	4.68	1.02	37.43
1935 Mean	5.37	3.14	2.30	3.10	3.07	6.23	3.55	1.10	4.80	1.21	3.74	1.24	38.85
12-year Mean	3.17	2.88	3.36	3.49	3.16	3.69	4.15	3.87	4.72	3.31	3.43	2.78	42.01
SWIFT WATERSHED													
West Ware	4.44	2.94	1.83	3.03	1.81	5.24	2.61	.92	4.57	1.60	3.75	1.09	33.83
Enfield	5.40	3.72	2.07	3.76	2.63	5.65	2.42	.74	5.17	1.27	4.10	1.22	38.15
Greenwich	5.05	2.32	1.85	2.56	2.54	5.82	3.61	.73	4.63	1.42	3.89	.89	35.31
North Dana	5.77	3.06	1.93	3.45	3.80	5.82	2.83	1.27	5.18	1.51	4.24	.71	39.57
Dana	4.49	2.14	2.13	3.74	3.38	4.83	3.49	1.13	3.45	1.62	4.21	.89	35.50
Packardsville	4.14	2.43	1.84	2.79	2.60	6.18	2.89	.94	5.33	1.50	4.36	1.03	36.03
Prescott	4.40	2.53	1.62	3.13	2.47	5.92	2.46	1.08	5.22	1.18	4.18	.81	35.00
Shutesbury	5.71	3.08	1.83	3.27	2.68	5.80	4.18	1.30	5.82	1.36	4.75	1.19	40.97
New Salem	5.55	2.73	1.43	2.59	3.00	5.87	3.05	1.16	4.92	1.26	4.72	1.02	37.30
Wendell	4.34	2.55	1.62	3.11	3.11	6.28	2.29	.88	4.83	1.62	4.69	1.93	37.25
Petersham**	7.09	3.43	2.23	4.12	2.32	5.64	2.08	1.49	4.70	1.11	5.04	1.04	40.29
1935 Mean	5.12	2.81	1.85	3.23	2.76	5.73	2.90	1.06	4.89	1.40	4.36	1.07	37.18
16-year Mean	3.25	2.98	3.35	4.11	3.47	4.65	4.16	4.09	4.50	3.14	4.12	3.13	44.95

* Station maintained by Metropolitan District Water Supply Commission.

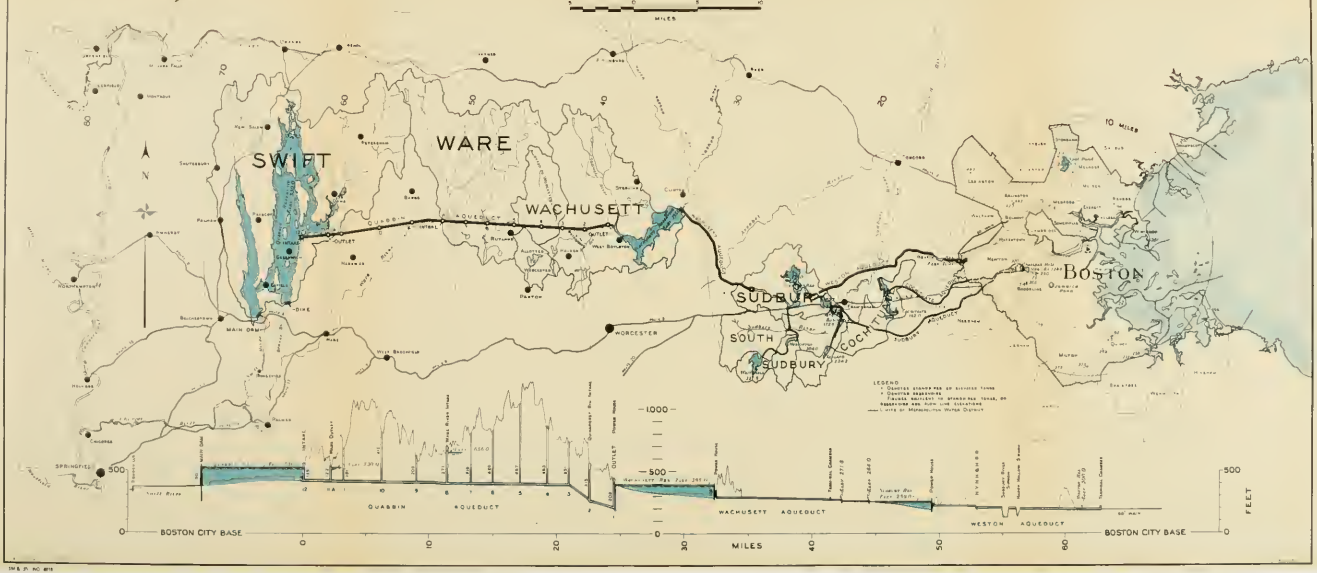
** Station maintained by Metropolitan District Commission.

Data for all other stations obtained through courtesy of State Department of Public Health.

SUMMARY OF MONTHLY RAINFALL IN INCHES ON THE WARE AND SWIFT WATERSHEDS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
						WARE WATERSHED							
1924	3.63	2.00	2.10	5.66	2.89	1.14	2.77	4.89	5.05	.07	3.38	2.10	35.68
1925	2.54	2.23	5.00	2.86	2.27	4.29	4.94	1.86	5.16	4.54	3.40	2.72	41.81
1926	2.42	4.06	2.80	2.35	2.18	2.72	2.67	2.81	1.46	5.25	5.63	3.29	37.64
1927	2.61	3.34	1.54	2.12	3.94	2.62	7.32	6.95	3.39	4.76	6.97	5.91	51.47
1928	2.49	3.16	1.77	4.59	2.77	6.79	5.98	5.96	3.29	1.69	2.04	1.49	42.02
1929	4.19	3.04	3.31	5.44	4.52	3.08	.99	1.71	2.60	2.24	2.97	2.68	36.77
1930	2.08	1.99	3.03	1.63	2.82	3.42	7.19	1.50	2.33	2.63	2.85	1.57	33.04
1931	2.40	2.44	5.12	2.91	5.15	4.68	3.50	7.61	2.25	2.97	1.39	3.34	43.76
1932	4.65	1.96	5.11	1.77	1.56	1.63	4.41	4.24	6.48	6.59	4.34	1.97	44.71
1933	2.28	3.87	5.31	5.47	2.59	2.24	2.89	5.10	10.17	4.99	1.34	2.87	49.12
1934	3.37	3.32	2.94	4.02	4.23	5.42	3.64	2.66	9.63	2.73	3.12	4.20	49.28
1935	5.37	3.14	2.30	3.10	3.07	6.23	3.55	1.10	4.80	1.21	3.74	1.24	38.85
Mean	3.17	2.88	3.36	3.49	3.16	3.69	4.15	3.87	4.72	3.31	3.43	2.78	42.01
						SWIFT WATERSHED							
1920	2.21	4.88	3.18	6.10	3.45	5.96	3.31	5.17	6.92	1.17	5.81	6.36	54.52
1921	2.42	2.65	3.69	8.61	3.32	4.33	6.47	3.70	2.71	2.27	6.52	2.49	49.18
1922	1.55	3.00	5.52	2.06	4.69	11.83	5.34	4.37	2.80	3.42	1.82	3.43	49.83
1923	6.55	1.90	2.57	4.66	2.31	3.40	2.44	3.51	2.04	5.53	5.29	4.69	44.89
1924	4.18	2.10	1.34	5.41	3.37	1.72	2.48	3.56	5.23	.06	2.98	2.16	34.59
1925	2.53	3.42	4.76	3.12	2.64	4.41	6.39	1.98	4.22	4.51	3.52	2.67	44.17
1926	2.73	4.12	3.26	2.58	1.80	3.23	3.41	3.63	1.50	5.66	6.17	2.94	41.03
1927	2.48	3.46	1.59	1.97	4.85	3.79	6.93	6.58	2.94	4.65	8.23	5.72	53.19
1928	2.56	3.10	2.21	4.93	2.79	7.22	6.20	7.65	3.75	1.61	2.30	1.25	45.57
1929	4.48	3.36	3.28	6.37	4.51	3.29	.99	1.65	4.55	2.57	3.12	3.66	41.82
1930	2.17	1.90	3.45	1.21	3.65	3.98	5.53	1.76	2.86	2.35	3.57	1.53	33.97
1931	2.91	1.81	4.07	2.90	6.51	4.64	3.04	6.62	2.38	3.34	1.57	3.73	43.53
1932	4.37	2.45	4.27	2.49	1.90	2.51	5.25	4.04	5.24	4.27	4.75	1.96	43.49
1933	2.33	3.66	5.04	6.13	2.33	2.86	2.45	6.94	10.32	4.69	1.43	3.42	51.60
1934	3.42	3.11	3.52	4.03	4.58	5.44	3.45	3.21	9.71	2.82	4.44	2.96	50.69
1935	5.12	2.81	1.85	3.23	2.76	5.73	2.90	1.06	4.89	1.40	4.36	1.07	37.18
Mean	3.25	2.98	3.35	4.11	3.47	4.65	4.16	4.09	4.50	3.14	4.12	3.13	44.95

WATER SUPPLY — METROPOLITAN BOSTON



APPENDIX TO REPORT OF CHIEF ENGINEER

GEOLOGY OF REGION IN WHICH QUABBIN AQUEDUCT AND QUABBIN RESERVOIR ARE LOCATED

Chapter 321, Acts of 1927, provides that "The Commission shall collect and publish in its reports such information as to the geology of the region in which any of the works which it is authorized to construct may be located as may be of value in connection with the geological history of the State."

The geological work has been done by Frank E. Fahlquist, Senior Civil Engineer, in consultation with Charles P. Berkey, Consulting Geologist, and the following report summarizes previous geological information contained in Annual Reports of 1927, 1928 and 1929, and covers also such additional geological information as has been gained up to date.

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Introduction

The extension of the water supply system of the Boston Metropolitan District to the Ware and Swift rivers involved the construction of the Quabbin Aqueduct, a tunnel in solid rock 25 miles in length, extending westerly from Wachusett Reservoir to the valley of the Swift River where the Quabbin Reservoir will be built. The present system as well as the additions thereto are shown on the map entitled "Water Supply—Metropolitan Boston." The portion of Quabbin Aqueduct from Wachusett Reservoir to the Ware River, about 13 miles in length, was practically completed in March, 1931, and water of the Ware River then diverted to the Wachusett Reservoir. The extension of Quabbin Aqueduct to the Swift River at Quabbin Reservoir was begun in 1931 and practically completed in the fall of 1935.

The Quabbin Reservoir requires two dams, one across the Swift River Valley, known as the Main Dam, and the other across the valley of Beaver Brook, known as the Dike. At the Main Dam a stream control diversion tunnel was constructed in rock at the westerly end of the dam, and at both the Main Dam and the Dike concrete cut-off walls to rock, formed by a succession of concrete caissons sunk through thick glacial overburden, have been completed. The work of constructing the embankment above the caissons at the Dike is under way and a similar contract is being prepared for the embankment at the Main Dam.

Geological Problems

The geological problems confronted in locating the tunnel sufficiently deep in bed rock to lie beneath surficial weaknesses and buried gorges involved the following features: the location and depth of old stream channels; determination of the kinds and character of the rocks through which the tunnel passes and their behavior during and after construction; the possibility of utilizing rock removed from the tunnel excavation for concrete aggregates; a proper distribution of shafts to secure the desired excavation progress, located at low points in the topography where deep excavations through earth would be avoided; the position and character of the weak spots and their estimated effect upon the feasibility of the tunnel construction; the probable effect upon ground water circulation and estimated leakage into the tunnel.

The problems at the Main Dam and Dike involved chiefly the character of the rock and the material overlying it at the sites of these structures and the location in the vicinity of material of suitable character for building the embankments.

The necessary preliminary investigations to determine suitable locations of structures and the construction of these works have contributed substantially to an understanding of the geology of the region. Investigations were made to determine the following: grouping of the several rock types into formational units; determination of the character and thickness of the schist rocks, the banded rocks or gneisses and of the original sediments from which the schists and the gneisses were largely derived; determination of the structural relation of the schists and gneisses of the district one to another and also their relation to the Oakdale quartzite and the Worcester phyllite formations which are considered to be of Carboniferous age; determination of the mode of emplacement of the granite and the amount of replacement accomplished by the invasion of igneous material into the older metamorphic formations; determination of the influence of remnant schist masses engulfed in the granite; correlation of formations and their geologic age.

An important contribution to Massachusetts geology was made in 1917 by the United States Geological Survey in the report on "The Geology of Massachusetts and Rhode Island" by B. K. Emerson. This report contains the most complete information available regarding the rocks of the State, but in the opinion of some geologists it has raised certain questions regarding particularly the geologic structure of the formations, their geologic age and the correlation of formations of adjoining areas.

Tunnel Location

The earlier stages of geological investigation were concerned primarily with the location of the tunnel lines and the selection of suitable shaft sites. Of first concern was the thickness of glacial drift, the depth of pre-Glacial river channels and their bearing on the location of the tunnel grade.

The engineering requirements of the project placed the following limitations on the location of the shafts and tunnel:

1. The easterly terminus of the tunnel, Shaft 1 (See Plate 1), was limited to some point adjacent to Wachusett Reservoir; the westerly terminus, the portal at Shaft 12, was limited to a suitable point along the east side of the proposed Quabbin Reservoir.
2. An intake shaft, Shaft 8, the location of which was restricted not only by natural and engineering requirements but also by legal limitations, was to be constructed on the Ware River near Coldbrook.
3. The location of a shaft, Shaft 2, was selected near the junction of Trout Brook and the Quinapoxet River in order that the combined flows of these streams could, if desired, be diverted into the tunnel.
4. It was important to have the construction of the easterly section of the tunnel between Shafts 1 and 8 completed early in 1931 to permit the diversion of the Ware River flows. This portion of the tunnel, therefore, was designed to be excavated from eight shafts spaced as nearly at equal intervals as the topography would permit.
5. Fewer shafts were necessary for the westerly section, between Shaft 8 and the portal at Quabbin Lake, because more time was available for its construction. The westerly section was therefore laid out to be constructed from only four shafts or seven headings, Shaft 11–A being constructed only as a waterway shaft.

Quabbin Aqueduct as constructed extends from the northwest side of Wachusett Reservoir south of the village of Oakdale to a point near Quabbin Lake about one mile south of Greenwich Village. Excavation was carried through solid rock throughout the entire length of the tunnel, the amount of rock cover above the tunnel varying between 55 and 800 feet. In the easterly 3½ miles the tunnel invert lies between 200 and 385 feet above the Boston City Base.* At the portal the invert is at an elevation about 414 feet above Boston City Base.

The completed aqueduct will fulfill several functions: (a) it will furnish a means of bringing water from Quabbin Reservoir, which will have a maximum flow line elevation 530 feet above Boston City Base, to Wachusett Reservoir; (b) it will permit at Shaft 8, at an elevation 656 feet above Boston City Base, diversion by gravity of the flood flows of the Ware River into either Quabbin or Wachusett reservoirs; (c) it will permit at Shaft 2, at an elevation 540 feet above Boston City Base, diversion of flows of the Quinapoxet River to Quabbin Reservoir, if desired. The flow of water in the tunnel will be controlled by gates at the Wachusett Reservoir end. Water flowing west through the tunnel will normally enter Quabbin Reservoir through Shaft 11-A located about 2½ miles east of the portal. When the flow is to the east, water from Quabbin Reservoir will enter the tunnel through Shaft 12 and be discharged into Wachusett Reservoir through Shaft 1.

Quabbin Aqueduct is lined throughout with concrete, and, except for circular sections about 500 feet in length at the easterly end and 200 feet at the westerly end, is of horseshoe shape 12 feet 9 inches high by 11 feet wide with weep holes which prevent water pressure on the lining.

The circular sections are 12 feet 9 inches in diameter with the lining grouted against the rock to prevent leakage either into or out of the tunnel. After completion of Quabbin Reservoir the hydraulic grade of the tunnel will generally be 100 feet or more above the tunnel roof.

The construction shafts have an inside diameter of 14 feet and are lined with concrete which was placed as the shafts were excavated, to avoid the hazard of falling rock. This size of shaft was sufficient to allow the installation of double hoists for the removal of tunnel muck and provided space for water and

* Approximately 6 feet below mean sea level as determined by the U. S. Coast and Geodetic Survey.

compressed air pipes, electric wiring, ventilation pipes and emergency exit ladders. Ledge, except at Shaft 3, was from 3 feet to 34 feet below the surface. At Shaft 3 it was necessary to sink a concrete caisson through 61 feet of earth to reach bed rock.

For shaft and tunnel excavation the contractors were paid at the contract unit prices for fixed volumes of excavation and fixed thicknesses of lining. A typical section of the tunnel is shown in Figure 1. The minimum thickness of lining was established for each cross section by a so-called "A" line beyond which no points of rock were allowed to project. In sound rock this was fixed at 3 inches on the side walls and invert and 8 inches on the arch. Except where permanent timber support was required the "B" line, which was generally the pay line for both excavation and concrete, was 12 inches from the "A" line on the side walls and arch and 2 inches on the invert. The "B" line was intended to represent a fair average of the irregular rock breakage, the actual average of which for the entire tunnel was about 10½ inches (See Plate 12). The normal volume of rock excavation in the tunnel was about 6.8 cubic yards per linear foot. Concrete lining averaged about 2.1 cubic yards per linear foot.

General Geologic Setting

The tunnel crosses a portion of the upland of central Massachusetts known geologically as the Worcester County plateau, a large part of which stands between 1,000 and 1,200 feet above sea level. Protruding above the general level of this area are isolated sections of considerably higher elevation called monadnocks, such as Mt. Wachusett, Elevation 2,000, and Asnebumskit Hill, Elevation 1,400. Geologic investigators[1] have previously noted the uniformity in the contour of the horizon line and have recognized in the general correspondence of the summits of the parallel ridges the former existence of a nearly uniform surface sloping gently toward the southeast with but few areas rising above it. Geologists have reasoned that in some past geological time this part of the state was eroded nearly to sea level, resulting in the formation of a plain, which has been designated as the Cretaceous peneplain from the geological period dating its development.

In general the hills and valleys are oriented in a north-south direction which is closely parallel to the folds in the geologic structure of the area. There are exceptions, however, which are sufficiently numerous to indicate that dissection or erosion of the ancient surface or peneplain was not controlled entirely by the distribution and structure of the underlying rock formations. An explanation of this has been advanced by Crosby[2] who believed that the peneplain at the time of its fullest development was covered by a thick mantle of sediments upon which a drainage pattern was developed without much regard for the structure of the underlying hard and soft rocks. At this stage of the erosional cycle the stream gradients were steepened and the rivers rejuvenated as the result of crustal disturbances. The rivers then became entrenched in the thick mantle of weathered rock and soil deposits. By the time these residual deposits were removed the streams had been superimposed on the older crystalline rock floor. The pattern of this ancient drainage system can be partly traced and reconstructed except in those areas where the valleys have been too deeply buried by glacial deposits.

As the ice sheet advanced during the succeeding epoch, known as the Glacial period, several of these valleys were slightly deepened and widened and the topography somewhat modified by ice erosion. As the glacier retreated large quantities of rock material which had been gathered by and frozen into the ice were deposited, in general, to rather shallow depths in the higher elevations but accumulated to considerable depths within the valleys. Since the Glacial period the regular surface geological processes have operated in a comparatively simple manner, the main feature being continued erosion of the glacial drift deposits.

[1] Alden, Wm. C., Physical Features of Central Massachusetts, United States Geological Survey, Bulletin 760, 1924, pp. 15–18.

[2] Crosby, W. O., Geological History of the Nashua Valley during the Tertiary and Quaternary Periods, Tech. Quart. Vol. 12, 1899, pp. 288–324.

Ancient, Pre-Glacial, or Tertiary Drainage Courses

Many of the streams of this section are too small to have excavated the broad and deep depressions which they now occupy. There are in the topography numerous notches or gaps cutting through rock divides which are now unoccupied by streams. These features, which are duplicated many times throughout New England and other sections of the country, have long been recognized by geologists as being related to the pre-historic river systems developed during a long period of erosion occurring before the Glacial period. The most important of these rivers are shown in Figure 2 and are summarized as follows:

1. The Tertiary Stillwater River. In the southern rim of the Nashua Valley at the head of Quinsigamond Valley there is a depression or gap one-half mile wide at an elevation about 440 feet above sea level. Three miles farther west and extending north from Oakdale is the valley of the Stillwater River. The normal course of that stream in early Tertiary times, before extension of the Nashua Valley westward, continued southerly through this gap into the Quinsigamond Valley and connected with the Blackstone Valley. There is also the possibility that before this time the Stillwater River flowed in a more southerly direction from the valley north of Oakdale through the valley of Malden Brook, leaving a gap near Summit at approximately 660 feet above sea level.

2. The Tertiary Quinapoxet River. The course of the tributaries of the Quinapoxet River suggests the earlier existence of two separate river systems. One course carried drainage from the southeast slopes of Mt. Wachusett by way of Governor and Trout Brook valleys, thence by way of the Quinapoxet River, Chaffin Pond and the gap at Elevation 760 south of Chaffin Pond into North Pond, to a larger valley at Worcester. The other, designated by Perry[1] as the "Auburn River," carried drainage from the south and southwest slopes of Mt. Wachusett by way of South Wachusett Brook and Cobb Brook valleys, Quinapoxet River Valley, Maple Spring and Eagleville Ponds, into Tatnuck Brook Valley; and is suggested by the gap at the head of Tatnuck Brook Valley at an elevation of about 820 feet above sea level. It seems probable that the "Auburn River" was first beheaded at a point in the vicinity of Quinapoxet Pond by a backward cutting tributary of the Quinapoxet, the course of which lies northwestward from Unionville. This suggestion appears reasonable in the light of information obtained later from the geologic section of the tunnel excavation which showed that a fault, striking in a northwesterly direction, coincides with the course of the valley.

3. The Tertiary Nashua River. During early Tertiary times, while the river systems noted above were eroding their valleys, the Tertiary Nashua River was rapidly cutting back (westward) over the softer micaceous schists underlying the main part of the valley floor. Crosby[2] has suggested that in one stroke the Stillwater-Quinapoxet system was diverted to the Nashua by the cutting away of the divide above Quinsigamond Valley, the component parts of the Quinapoxet having been previously captured by the Stillwater. The rock floor of the pass at the head of Quinsigamond Valley is at an elevation of about 440 feet above sea level, and that at the confluence of the Quinapoxet-Stillwater rivers is less than 375 feet above sea level.

4. The Tertiary "Rutland" River. A large part of the drainage from the western slopes of Mt. Wachusett was originally directed through the valley now occupied by the upper reaches of the Ware River, and through the valley now occupied by Long Meadow Brook, thence by way of Long Pond, Browning Pond, and Seven Mile River. Along this course there is a gap between Long and Browning ponds at an elevation of about 920 feet.

5. The Tertiary Burnshirt River. A southeasterly extension from Coldbrook of the Burnshirt and Ware River valleys is suggested by the topography, especially in the vicinity of Muddy Pond, situated at the head of the valley now occupied by Deans Reservoir, Brooks Pond and Five Mile River. That this course was identified with the earlier Tertiary history of the Ware River system is indicated by the gap south of Muddy Pond at an elevation of about 880 feet.

[1] Perry, J. H., The Physical Geography of Worcester, Mass., Worcester Natural History Society, 1898, p. 40.
[2] Op. cit.

6. The Tertiary Ware River. The Ware River Valley above Barre Plains becomes narrower and joins the valley of the Ware and Burnshirt rivers in the vicinity of Coldbrook. The smaller tributary, Prince River Valley, has special significance in that it probably was part of the earlier Tertiary Ware River Valley before the divide to the east had been eroded. These conclusions are more fully presented later in the discussion concerning interpretation of profiles obtained from borings.

7. The Tertiary Moose River. The presence of a gap at an elevation of about 770 feet between Mill and Winimusset brooks, and the position of the valleys occupied by these two brooks with respect to Moose and Pine Hill brooks, suggests two pre-Glacial stream possibilities, one of which, shown in Figure 2, indicates that Moose Brook Valley, although offset one mile farther west, had an erosional history in common with Mill and Winimusset Brook valleys. The other possibility is that the pre-Glacial Prince River during its earlier history was directed through Mill and Winimusset Brook valleys by way of what is now part of the Ware River Valley.

8. The Tertiary "Muddy" River. The valley of Muddy Brook is one of the most impressive of those crossing the tunnel line (see Plate 1). Study of the topography from the map and in the field suggests that at some time the East Branch of the Swift River flowed through this valley. Upon investigation by borings the divide in the vicinity of Dead Pond was found to be composed entirely of glacial drift. The rock floor of the valley through this area is at about Elevation 480, whereas the surface divide is approximately 70 feet higher.

Reconstructing the pre-Glacial or Tertiary drainage pattern was important in indicating the areas where the underlying rock floor might be lower in elevation than was indicated by surface conditions. The limits of many of the pre-Glacial valleys are obscured by extensive glacial drift deposits of uncertain thickness. Because of the uncertainty as to the topography of the rock floor, such areas were recognized as being more important than others where geologic conditions were more easily interpreted. These preliminary investigations outlined the critical areas throughout which more detailed investigations should be made by diamond drill borings.

Glacial Drift Deposits

The greater part of the area traversed by the tunnels is covered by a glacial deposit known as a ground moraine. This type of deposit is commonly found in an unsorted condition and consists of a heterogeneous mixture of rock flour, sand, gravel, and boulders. It is a relatively shallow deposit compared with other types of glacial drift. In general the ground moraine is found in the higher areas and upon the side slopes of the valleys which, upon retreat of the glacier from the region, carried the glacial waters derived from the melting ice. As a result, this type of deposit, sometimes called hardpan by the engineer, is comparatively free from the assorting effect of water.

During the recession of the glacier many of the valleys were periodically blocked by glacial drift and ice. Water derived from the melting ice was thus ponded, forming temporary glacial lakes which received large quantities of well assorted deposits transported by glacial rivers. This phase of the glacial history may be recognized in the modified character and mode of occurrence of the deposits, which consist largely of stratified fine sand and banded clay or rock flour. The surface topography within these lake areas is generally flat with small irregularities and depressions. One of the most notable of these temporary lakes was the glacial Lake Nashua of Crosby[1] which covered the drainage area of the Nashua River from Boylston to East Pepperell, with an arm running to Fitchburg. The present Wachusett Reservoir occupies a portion of the bed of this lake.

Investigations in the Valleys

Valleys whose outlets were kept open throughout the period of glacial recession contain deposits of a modified character, the irregular structure and coarseness of which indicates an origin other than in the quiet waters of a glacial lake. The lower sides and bottoms of these valleys contain irregularities in the general

[1] Op. cit.

surface topography in the form of ridges and terraces which are composed mainly of sand and gravel, indicating deposition by glacial streams. Some of these sediments were deposited in front of the retreating glacier as a sheet or outwash, some beneath the ice in sub-glacial river channels, and others on top of the ice. As a whole they form a curious assemblage of flat terrace-like areas and steep and gradual sloped knolls and ridges of varying magnitude. Such deposits of glacial drift are known as kame deposits, fine examples of which are found in the valleys of Muddy Brook and the Swift River.

There are also other deposits of a semi-modified and unmodified character whose form and surface character indicate an origin near the front of the retreating ice sheet. Alden[1] has recognized these deposits as recessional moraines, has traced their approximate boundary lines, and has differentiated the several stages of glacial retreat which contributed toward their development. In surficial configuration these deposits form knolls and ridges of irregularly stratified sand and gravel. Irregular or bowl-like depressions, many of which contain small ponds and bogs, are interspersed throughout the morainal area. The difference in the relief of these humps and hollows ranges from five feet to not more than a hundred feet. The topography is not imposing but in general it is peculiar and characteristic, appearing somewhat like a large dump of earth and rock material.

Specific Geological Investigations

Geological investigations of the Quabbin Aqueduct included briefly: (a) construction of an outcrop map; (b) delineating areas where the glacial drift was so thick that the rock floor topography and character were uncertain; (c) tracing of pre-Glacial drainage courses; and (d) explorations by diamond drill borings. Borings carried to and into rock were completed in the conventional manner of doing such work. Since boulders five feet or more in diameter are not unusual occurrences in glacial drift derived from crystalline rock formations, borings were penetrated into ledge for distances varying between 10 and 20 feet in order to be certain that bedrock had been reached. At two of the shaft sites the rock formations were penetrated to a depth of 100 feet.

Investigation in Quinapoxet Valley

The Quinapoxet Valley for a distance of one mile east of Shaft 2 is covered with modified drift laid down in an early stage of Glacial Lake Nashua. Extending east of this section to the vicinity of Shaft 1 the deposits are of the morainal type, forming an almost continuous cover of variable thickness which made investigation by borings necessary. Such rock outcrops as were located indicated that the present stream does not flow in its original channel. Not only was there uncertainty as to the thickness of the deposits but it was impossible to state where the deepest channel in the rock floor was located. An extensive boring program, therefore, had to be planned to secure the necessary data. The greatest depth of drift penetrated by any of the borings (see Figure 3) was found to be 114 feet. Within this valley glacial drift is believed to be deposited to a depth of 175 feet more or less. The lowest point reached by borings in the rock floor of the valley was approximately 400 feet above sea level, causing the depression of the east end of the tunnel to a depth of approximately 200 feet to insure a sufficient thickness of rock cover.

Investigations in Ware-Prince Valleys

Abrupt change of the valley at Coldbrook from a north-south to an east-west course is a striking deviation from the normal trend of valleys throughout the district. A possible explanation of this unexpected change of course has been previously suggested in the discussion pertaining to pre-Glacial drainage courses. The interpretation presumes that the Burnshirt-Ware and Prince-Ware River valleys were originally separated, that during Tertiary time a tributary of the Prince River, etching out the valley now occupied by the Ware, cut through the divide and diverted the other stream. In the earlier stages of its development the Tertiary Burnshirt River flowed by way of the present Burnshirt-Ware valleys as far as Coldbrook, and thence southerly out of the district. The course

[1] Op. cit.

of the Tertiary Prince-Ware River was directed in somewhat the same manner as at the present time. Later the upper portion of the Burnshirt-Ware was diverted into the Prince-Ware course.

A series of seven borings across the Ware River on the site of the diversion dam at Shaft 8 (Figure 4) located the lowest point in the valley floor at about Elevation 607, which is approximately 40 feet lower than the flow line of the present stream. A profile through these borings developed the form of the floor and indicated the extent to which this ancient valley was filled with drift. The deposits throughout this area are of the recessional moraine type, extending southeasterly from this point along the Boston and Maine Railroad, and have partially obscured the Tertiary valley mentioned above. The elevation of the floor at this point favors the conclusion that the Tertiary Burnshirt River was diverted by a backward cutting tributary of the Prince-Ware River, which left the valley floor of the former higher than 600 feet above sea level. A boring placed one-half mile southeast of Coldbrook, at a point probably located within the Burnshirt Valley, found rock considerably above Elevation 600.

To check the reasoned conclusions concerning the geologic history, and also to determine the profiles of these valleys, several borings were made near the confluence of the Prince and Ware Rivers at Barre Plains. These indicated a great thickness of glacial drift over the rock floor. One boring, for example, after penetrating 161 feet of glacial drift showed rock at Elevation 434, which was only a few feet above the projected tunnel grade. That the floor was low at this point had been foreseen, but without further explorations it was not possible to determine whether this condition was confined within the Ware Valley or the Prince Valley or was common to both. In order to determine the extent of this depression, and to fix the point at which it would be safe to cross the valley along a new tunnel line location, several additional borings were located farther east along the tunnel line. These investigations (see profile, Figure 5) indicated that rock along the line in the Ware Valley was sufficiently high for an adequate rock cover over the tunnel and that the low floor section was confined to the Prince Valley. It became necessary then to select a crossing under the Prince Valley where higher rock could be found. From the study of erosional processes, river and glacial, which were responsible for the formation of this valley, it seemed evident that this desirable condition would be found farther north. Consequently, several borings were placed along a new location of the tunnel line, and the result confirmed that conclusion. Subsequent investigations along this line indicated a rock valley buried to a maximum depth of approximately 110 feet. The lowest point of the valley floor was determined to be at about Elevation 480.

One possible interpretation of the facts would account for the low floor at the confluence of the Prince and Ware Rivers as being the result of erosion by the Ware River. This interpretation would assume, however, an abnormal gradient in the rock floor of the Ware Valley throughout the section between Coldbrook and Barre Plains. Additional explorations between these localities indicated that this interpretation was not correct, that the floor gradient of the Ware Valley was normal, and that a large part of the 200-foot drop between Coldbrook and Barre Plains was confined to a relatively small area. Overdeepening of the valley by glacial abrasion appears to be the most reasonable explanation of the origin of this rock depression.

Investigations at the Portal Site

The first steps in the sub-surface investigations of the west portion of the aqueduct were made in Muddy Brook Valley along a line referred to as the "south line." Preliminary studies for the location of the west terminus of the tunnel contemplated the selection of a suitable portal site on the East Branch of the Swift River somewhere south of Quabbin Lake. The portal of the south tunnel trial line was located at a rock cliff a short distance from the Swift River, East Branch, and about one-fourth mile south of the lake. It was found, however, that location of the portal site along the east side of the lake would save from one-fourth to one-half mile of tunnel. It was also believed that a higher rock floor could be found in the valley of Muddy Brook along a line situated farther north. Preliminary studies narrowed the list of promising portal sites to two, one located at the extreme north end of Quabbin Lake and the other

about midway between the north and south ends of the lake. Several borings distributed at the most northerly site revealed the surface of rock at a sufficiently high elevation to make a portal at this point feasible, and thus take advantage of the shortest possible tunnel line.

Investigations in Muddy Brook Valley

The valley of Muddy Brook when viewed from the higher ground on either side is an impressive physical feature (see Plate 1). It is a fine example of a large valley now occupied by a stream apparently much too small to have accomplished such an extensive erosional effect. The broad floor of this valley is covered for more than a mile and a half with sand and gravel ridges of glacial origin. Some of the drift is only partially assorted and would indicate accumulation to almost any depth. There is nothing whatever to be seen in the valley bottom from surface inspection that would indicate either the form of floor profile or the quality of rock beneath.

Preliminary field investigations showed an irregular distribution of glacial drift and led to the belief that Muddy Brook Valley was the result of erosion by a pre-Glacial stream but that considerable deepening and widening and removal of minor eminences was accomplished by glacial erosion. How much of an effect these processes had on the final configuration of the rock floor it was impossible to foretell.

A rock profile developed from information obtained from several borings placed across a portion of the valley near the south line crossing (Figure 6) revealed a deeply buried rock floor in which the lowest point was approximately 45 feet above the projected tunnel roof. These explorations having shown a low rock floor on the south line, attention was transferred to the north line crossing, where it was hoped better conditions might be found. The results showed, however, a continuous low floor and also that the present divide in this area between the Ware and Swift River watersheds is formed entirely of glacial drift deposited to a maximum depth of about 140 feet. As a result of these studies, which indicated a rock cover over the tunnel roof of about 55 feet, the north line was accepted as the tunnel location.

Upon reviewing the Muddy Brook problem at a later date it was felt there were still several features which had not been as fully determined as was desirable. Borings on the north line had been located by lining up the lowest known portion of the valley floor as developed on the south trial line with the water gaps observed in the topography toward the northwest. This method, however, left an unexplored portion along the tunnel line in the vicinity of Dead Pond approximately one mile in length, much too long a stretch to be taken wholly for granted. The impossibility of determining from the information at hand just how much of the valley was due to pre-Glacial river erosion and how much to glacial scour was an additional reason for further exploration.

For this particular work it was considered practicable to develop a rock profile with the aid of the surface potential or resistivity method of geo-physical prospecting, by means of which estimates of the thickness of cover or depth to bedrock are based on electrical measurements. In order to be assured of the approximate reliability of the results similar electrical determinations were made at two points where the thickness of cover was already known from borings. In both of these cases the results were consistent with the borings.

A rock profile across the valley floor was thus developed which considerably extended the reliable information. Throughout the section in question the mantle of drift was shown to be rather thick but the elevation of the floor was found to be considerably higher than throughout the section farther west.

The Rock Floor

The district where the Quabbin Aqueduct is located is so heavily covered with glacial drift that a large part of the bedrock geology is seriously obscured; nevertheless, outcrops are sufficiently numerous to determine certain major features concerning the underlying geologic structure. The several rock formations occurring in this section of the state have been defined by Emerson[1] and their

[1] Emerson, B. K., Geology of Massachusetts and Rhode Island, U. S. G. S. Bulletin 597, 1917.

areal extent has been indicated on the geologic map of Massachusetts and Rhode Island. This geologic information was accepted as a working basis and proved to be immensely helpful. In reality it became the ready-at-hand guide in the early reconnaissance studies.

It was clear from these published sources of information and from field studies that several different rock formations, all of them crystalline, would be penetrated by the proposed tunnel. Some of the formations are metamorphosed bedded sediments while others are of igneous origin, the chief igneous rock being granite. The metamorphosed rocks vary from very fine-grained rocks, intermediate between slate and mica schist called phyllites, to fairly coarse-grained schists. Occurring with these are occasional beds of quartzite which in general are more massive than the schists. As a whole, the rock formations were considered to be of good quality and where they had not been disturbed too much by deformation it was felt they would not be likely to give trouble of any consequence during construction. A certain amount of faulting, where the rock might be badly broken, was anticipated, and it was believed that such weaknesses would be encountered despite the fact that no important fault could be located by surficial examination. The fact that nothing of this nature could be located was not considered significant because such features under weathering and erosion develop readily into depressions which later become obscured, thus removing from observation the very places of most concern to the engineer.

Before construction began a final review was made of all the old and new facts bearing on the tunnel project as well as the several questions previously raised.

The preliminary and more detailed geologic studies made it possible to answer some of the questions completely. It was readily determined that there were at least seven important geologic units sufficiently uniform within their own boundaries and yet varying enough one from another to be regarded as different geologic formations. It was also possible to determine approximately the formational sequence from one end of the tunnel to the other and indicate the length of tunnel within each formation. It was impossible to make a definite statement as to the location of faults or crush zones as none of importance were discovered in the exploratory work. It was necessary, however, to anticipate the probability of encountering such zones and to be prepared to provide timbering for the tunnel excavation through them.

It was apparent that the tunnel could be constructed successfully along any of the alternative lines so far as the rock formations themselves were concerned. Such structural weaknesses as might be encountered were expected to cross the tunnel line and would be encountered regardless of which line was followed. The choice of lines, therefore, turned, not on the character of the rock but directly upon its topography, especially the depths of buried channels, and also upon the relative advantages of the portal sites.

Record of Geologic Features of the Tunnel

A plan of recording geologic features was used that is believed to be particularly suited to projects of this kind. Special attention was given to four kinds of records; first, systematic field notes of observations taken directly from the tunnel walls, and transference of this data to a geologic section drawn as a profile of the tunnel; second, collection of typical samples representing the average of rock formations and any special conditions; third, a series of photographs of characteristic structures and underground conditions; and fourth, notes on special features and on rock interpretations which it is hoped will serve as a contribution to the geology of central Massachusetts.

The Geologic Section

In recording the geologic phenomena observed in the tunnel a continuous floor plan and sidewall profile was drawn on a scale of twenty feet to an inch. Plan and section are drawn side by side, giving opportunity to show graphically the strike of structures on the plan and the dip on the section.

Different rock types are indicated by characteristic conventional designs and all special structural features are represented, including formational boundaries, bedding, joints, and internal features such as the foliation or grain structure. Additional features which do not lend themselves to graphic representation are

indicated in descriptive notes on the drawings at the point of occurrence so that the geologic plan and profile carry a continuous series of abbreviated descriptions. Sixty such drawings are appended to this report.

Rock Samples

Hand specimens were taken systematically and continuously from a large part of the tunnel at 25-foot intervals. In certain stretches where the geologic conditions were more uniform and monotonous, samples were taken at 50, 100 or 250-foot intervals. In addition, whenever it seemed advisable, suites of specimens were collected for special study.

All of these rock samples have been properly labelled and arranged and are permanently housed in the intake building at Shaft 8 near Coldbrook where they furnish a visible record of the actual rock excavated throughout the entire length of the tunnel.

Photographic Record

In addition to the detailed geologic record presented on the profile sections, photographs were taken of those spots where features of special interest and significance were encountered. These features are mostly of a structural character and include banded or injection structures of pegmatite and granite in the schistose rocks, streaked and banded or flow structures characterizing the granite masses, and deformation structures of all kinds, particularly folds and joints. In this manner some of the characteristic details have been preserved with greater exactness than could otherwise have been done.

Geologic Interpretation

It is intended to give here a summary of the geologic returns of the Quabbin project. This portion of the report is essentially a composite of data gathered from all possible sources and assembled into as comprehensive a statement as seems justifiable. It, together with the other forms of records referred to under the preceding heads, is intended as a contribution to the geology of central Massachusetts.

Rock Formations

All rocks of the area have been greatly modified by metamorphic processes. Despite the great variety, the rocks may be grouped rather satisfactorily into three classes: (1) those of sedimentary origin, (2) those of igneous origin, and (3) those of doubtful origin consisting chiefly of hybrid or mixed rocks, in part igneous and in part sedimentary. In the excavation of the tunnel, two principal types of schist were penetrated. One of these is a brownish quartz feldspathic biotite mica schist typically developed between Shafts 4 and 5. This in general corresponds to the Paxton quartz schist of Emerson.[1] Another type is a brownish quartz mica (mainly biotite) schist typically developed between Shafts 3 and 4, 7 and 8, 9 and 10, and at Shaft 11. This is the Brimfield schist of Emerson.[2]

The Paxton feldspathic biotite schist is made up of two units separated by a distinctly different type, which is similar to portions of the Brimfield schist. The Paxton formation, therefore, is composed of three members, which have been designated as the upper, middle, and lower Paxton members.

The Brimfield schist type was found distributed both above and below the Paxton formation. Because of this it was necessary to recognize a new formation which has been called the Ware schist.[3]

Rocks of igneous origin occur throughout the tunnel, the most prominent occurrences being those of a gray gneissoid granite between Shafts 1 and 3 and 11 and 12. The granite occurring within the former limits has been mapped by Emerson[4] as part of the Fitchburg granite, and that within the latter limits as the Monson granodiorite.[5] A very dark granitic gneiss, called the Hardwick granite[6], occurs between Shafts 10 and 11.

[1] Emerson, B. K., op. cit., p. 62.
[2] Emerson, B. K., op. cit., pp. 68–71.
[3] Callaghan, E. A., Contribution to the Structural Geology of Central Massachusetts, Annals of the New York Academy of Science, Vol. 33, p. 63.
[4] Emerson, B. K., op. cit., pp. 232–233.
[5] Op. cit., pp. 241–243.
[6] Op. cit., pp. 238–239.

The areal distribution of formations is shown in Figure 7. The distribution, except for minor revisions, is essentially the same as that shown by Emerson.[1] In a few cases, formational boundaries have been redrawn to conform to the contacts exposed in the tunnel. The rocks of the large area mapped by Emerson as Brimfield schist in Hubbardston granite have been given new significance by assigning them to and mapping them as a new formation called the Ware schist. The designation of Hubbardston granite on the preliminary map has been dropped in the interest of simplification. As brought out in this report the Hubbardston granite is merely a special facies of the Fitchburg granite, which has intruded the schists and formed injection schists and gneisses. In a few cases this condition is shown on the map by a pattern similar to that designating the Fitchburg granite.

Emerson's classification of Brimfield schist has been retained, although occurrence of this type in four separate belts between Shaft 8 and the portal has been shown on the geologic section, Figures 8D, E and F, as Brimfield-Ware schist. Formations of only indirect concern to this report have been grouped. These include the sandstone and shale strata and diabase intrusions of the Connecticut Valley area, which are shown by only one pattern, and which are classified as "Triassic Sediments and Diabase Flows—Dikes." The rocks west of the Connecticut Valley are likewise grouped under a single pattern and are classed as "Schists and Gneisses West of Connecticut Valley." The Paxton schist formation, newly recognized as being composed of three members, is shown by a single pattern, because the areal distribution of the component parts is not known in sufficient detail to warrant mapping them. It might be noted that Emerson has mapped a few small areas of Brimfield schist enclosed by Paxton schist, which probably could be classed with the middle member of the Paxton formation. Additional exposures of diabase are shown, which are parts of several intrusive dikes emanating from the much larger diabase intrusions of the Connecticut Valley area.

The Worcester Phyllite

This formation does nor occur within the tunnel area. It has, however, an important bearing on the structural as well as the age relations of the tunnel formations. The Worcester Phyllite at its type locality, the Worcester "Coal Mine," has been recognized by Emerson and Perry[2] to be of Carboniferous age. This conclusion has been substantiated by White.[3].

In the "Coal Mine" area the rock is a distinctly carbonaceous and graphitic phyllite. The typically graphitic variety is very black and dense and is composed essentially of quartz, magnetite, biotite, and sericite minerals, together with variable amounts of ferruginous and carbonaceous earthy materials, all of which are thoroughly recrystallized. The whole rock exhibits a strong foliation, grain, or bedding.

A variation in composition is shown in the occurrence of a dark gray to black phyllite having a uniform but extremely fine grain and composed chiefly of quartz and muscovite mica or sericite in about equal amounts. It is very strongly laminated and often presents a distinctly slaty cleavage, although in some places the laminations are wavy, contorted, and crumpled, even down to microscopic scale (Plates 2 and 3).

The phyllite contains many large and small quartz veins which follow the foliation structure in all its detail of folds, crumples, and small distributed faults. Where more strongly quartzose beds are interbedded with the phyllite the quartz veins cut across the foliation without any trace of folding or contortion.

A common feature of the contact zone between the quartzite and phyllite in the area north of the Wachusett Reservoir and the fossil bearing outcrop of the "Coal Mine," is the occurrence of andalusite crystals. These do not penetrate the more quartzose beds but lie in all directions within the darker phyllitic layers. Emerson[4] has previously reported the occurrence of this andalusitic rock over an extensive area in Lancaster and Sterling and designated it as chiastolite

[1] Op. cit., Preliminary Map of Massachusetts and Rhode Island.
[2] Emerson, B. K., and Perry, J. H., Geology of Worcester, Mass., 1903, p. 29.
[3] White, Chas. David, Age of the Worcester Phyllite, Jour. Wash. Acad. Sci., 1912, pp. 114–118.
[4] Op. cit., pp. 64–65.

schist. In the geologic section (Figure 8A) the phyllite is shown as folded into a simple dome or anticline on the west and a trough or syncline on the east, the major portion of the arch having been removed by erosion, exposing the underlying quartzite.

The Oakdale Quartzite

In the easterly end of the tunnel (Figure 8A) there is an extremely fine-grained light to dark gray and reddish-brown phyllitic quartzite, which, according to Emerson, is part of the Oakdale quartzite formation. The composition of this is quite variable. In general it varies from a phyllitic quartzite or quartz-mica phyllite to a true quartzite. In its simplest facies it is composed chiefly of quartz and rather abundant carbonate (calcite or dolomite) with small amounts of zircon. It is distinctly granular but is nowhere thoroughly recrystallized although quartz, feldspar, carbonate, sericite, and magnetite are present as recrystallized minerals. A variation in color to reddish brown is due to very fine biotite mica, and that to a greenish gray is thought to be due to secondary chlorite, although other investigators have noted actinolite in small lenses which also might account for this color. Another variation seen in hand specimens on the surface, but which could not be recognized in the tunnel, is the segregation of biotite mica in thin bands.

Discontinuous quartz veins are almost always present, but never in association with feldspar. They more often occur with sharply defined borders, sometimes offset, revealing small faults. Introduced carbonate is very abundant—especially in the form of thin-vein fillings in the zones of greatest fracturing. Carbonate also occurs as a very thin veneer on some joint surfaces.

Surface exposures east of the tunnel (Plate 2) show a rock of somewhat variable composition varying from a massive quartzite to a very finely laminated phyllitic quartzite or quartz-mica phyllite. This rock is light to dark gray in color, and contains sericite which imparts a typical silvery sheen to cleavage blocks. Laminae average 2 to 3 mm. in thickness, and near the interbedded quartzite and phyllite are observed to lie closely parallel to the true bedding. In some areas the small crumples of the laminae appear to have been overfolded toward the west, but one small fault was observed which showed an overthrust toward the east. The grain size is everywhere strikingly uniform. When weathered the quartzite tends to break readily along the foliation planes and presents a somewhat leached appearance which is due to attack on the fairly abundant carbonate constituents.

The quartzite, east of the narrow belt of phyllite occurring within the reservoir near Oakdale, forms a belt approximately 1½ miles wide. It is regarded as an anticlinal structure or dome as indicated in the geologic section. West of an area of phyllite it again appears in a belt about one mile wide dipping toward the west where it grades into the Boylston schist.

The Boylston Schist

The weathered exposures of this rock present a rusty brownish color, but fresh fractures reveal a bright silvery appearance. In the tunnel the schist has a uniform grayish color and appears to have a somewhat variable composition. The rock generally occurs as interbedded layers and is composed of two principal varieties, namely, a fine-grained quartzose schist or phyllite and a coarser more micaceous schist. The quartzose varieties vary in occurrence from narrow bands a fraction of an inch thick to massive beds several feet thick constituting the major portion of the rock. The coarse micaceous bands are usually minutely crumpled and crushed.

The quartzose bands could be termed quartzites. They have an average grain size of 0.1 mm., and in addition to the abundant quartz contain perfectly oriented muscovite and biotite mica and chlorite minerals and occasionally garnet and pyrite (Plate 3).

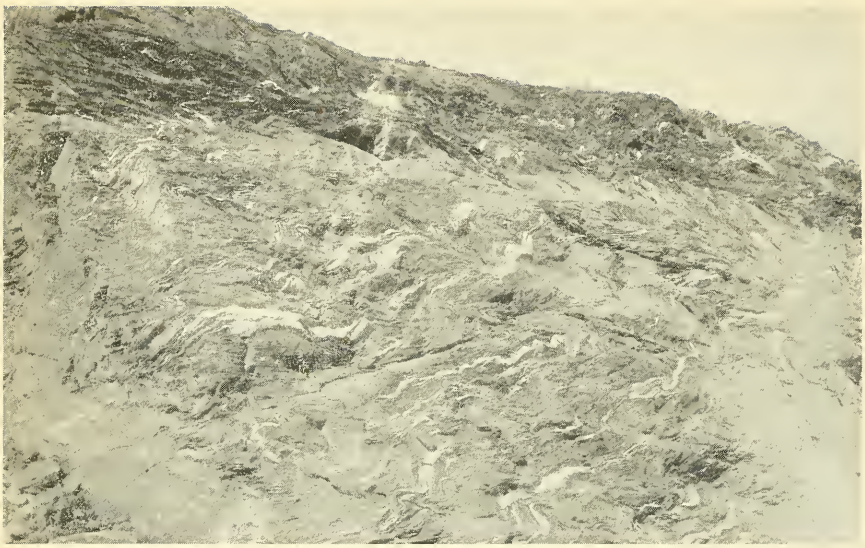
Andalusite crystals are frequently present in the more micaceous bands. The foliation is often seen to be displaced around these crystals and is sometimes curved and contorted. The crystals are larger and more abundant in the vicinity of pegmatite and quartz intrusions. Alteration of andalusite to an aggregate of fine biotite and muscovite mica is indicated on the embayed or irregular mar-

Plate 1

Outlet Works at Shaft 1.
View of Quinapoxet River and Wachusett Reservoir.

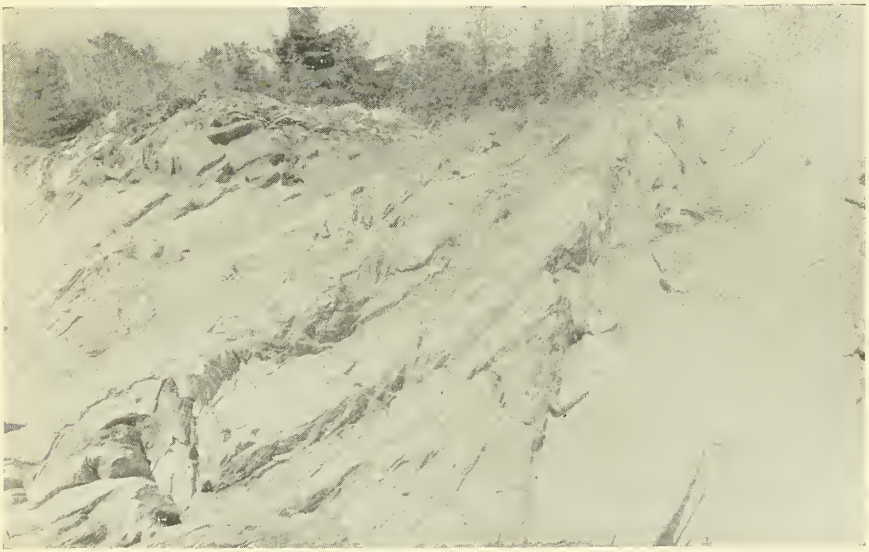
Muddy Brook Valley.
The Cretaceous peneplain is traced by the distant skyline.

Plate 2



Crumpled Phyllite.

This view was taken on north shore of Wachusett Reservoir in area mapped as Worcester phyllite. The minutely contorted structure and sinuous bands of vein quartz are typical of the formation.

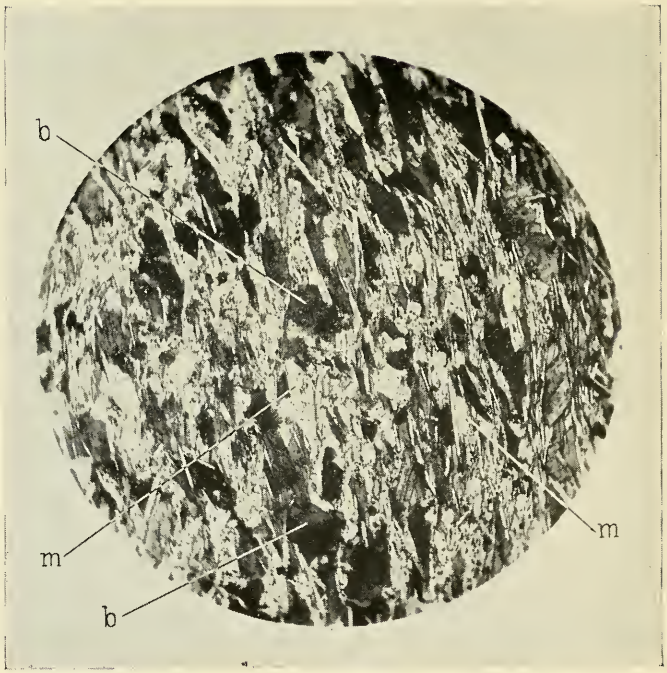


Crumpled Interbedded Quartzite and Phyllite.

A feature is the strong crumpling of phyllitic layers. The small overthrust faults are displaced toward the east and the narrow sinuous bands are vein quartz.

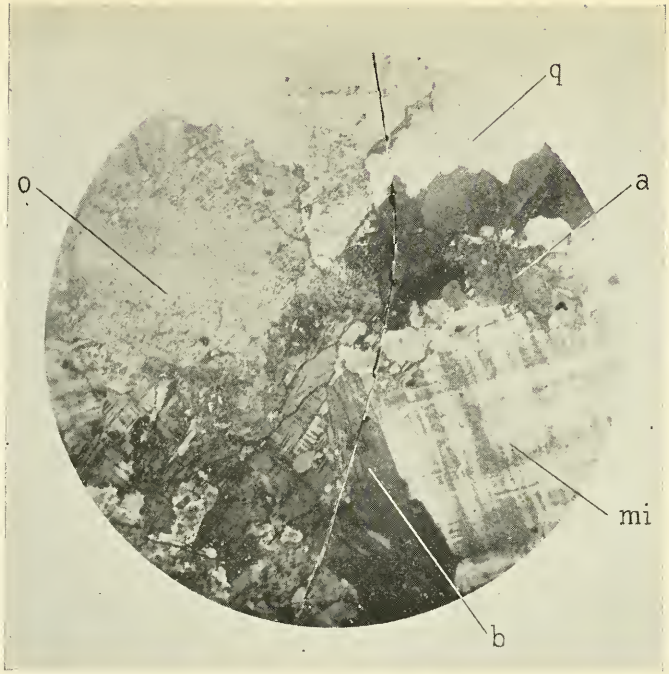
Photomicrograph in plain light showing the structure and general composition of the Worcester phyllite. Note the crinkled deformation structure and the fine streaked habit of the rock. The light and dark portions are made up of the same constituents but in variable proportions, the lighter portion being very fine granular quartz and the darker chiefly fine flaky mica.

Magnification 30 ×



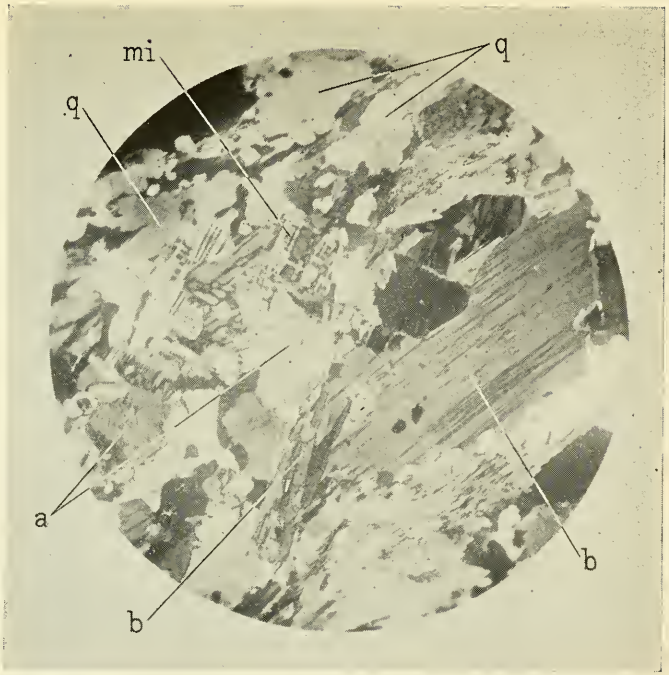
This photomicrograph in plain light shows the internal structure and composition of the Boylston schist. Note the strong schistose structure resulting from the orientation of light and dark mica. The scattered large flakes are biotite mica (b), and the light shreds are muscovite mica (m). The other constituents are chiefly quartz and granules of magnetite.

Magnification 30 ×

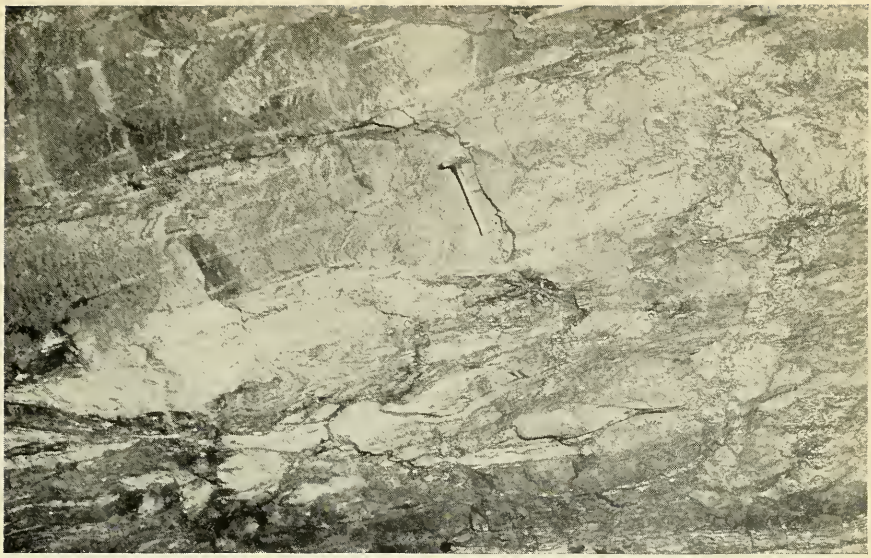


Photomicrograph of normal Fitchburg granite. The rock is composed of orthoclase (o), microcline (mi), albite (a), quartz (q), biotite (b), and muscovite, with small amounts of accessory minerals, apatite and zircon. There is a little secondary alteration producing small amounts of sericite (light specks on the feldspars), chlorite, and iron oxide. The rock is massive and the most noticeable feature is its composition, at least 95% being feldspar and quartz.

Magnification 30 ×

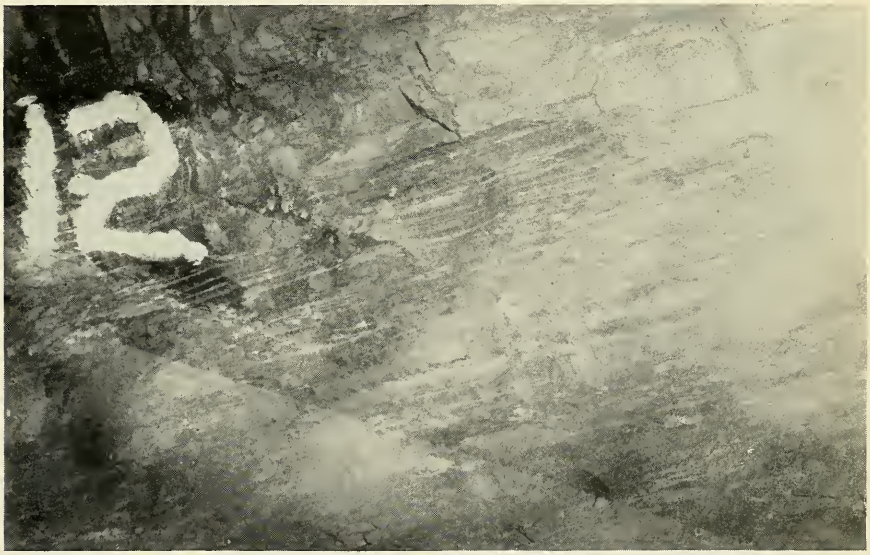


Photomicrograph of Fitchburg granite of gneissoid habit taken in polarized light for comparison with normal Fitchburg granite from which it differs in texture, structure, and compositional proportion. The constituents are essentially similar, microcline (mi), and albite (a) being the principal feldspar representatives, which are associated with abundant quartz (q), biotite (b), and muscovite. The accessory minerals are zircon, magnetite, and apatite. This rock, because of its strong foliated structure and mineral content, is judged to be of a mixed character, containing material derived both from the older schist and from the granite magma, which was intruded. Magnification 30 ×



Brimfield Schist.

The massive beds are quartzite. The remaining portion shows the typical biotite schist containing small lenses and bands (light patches) of pegmatite.

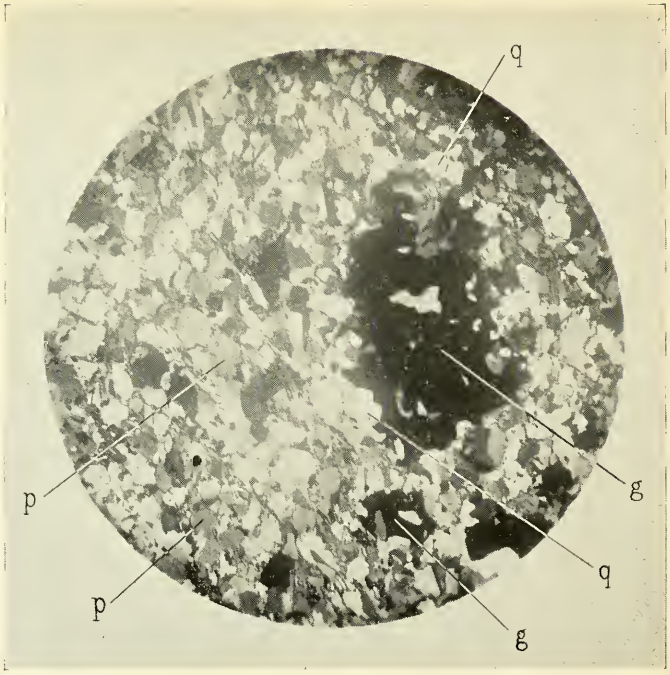


Typical Banded Paxton Schist.

The narrow light-colored bands are parallel to the foliation and bedding structure, and indicate original sedimentary layers. The persistence of such structural features made it possible to reconstruct the geologic section with considerable accuracy.

Photomicrograph of Brimfield schist taken in plain light. The foliated structure of the rock is a notable feature. The light streaks are made up chiefly of quartz. The dark streaks are chiefly biotite, with small amounts of accessory constituents. A large garnet is shown at one side of the field.

Magnification 30 ×



Photomicrograph in polarized light of phyllitic quartzite, which occurred as a band in the Hardwick granite. The most striking feature in composition is the abundant occurrence of quartz (q) and large sprawling garnets (g). The other constituents are plagioclase feldspar (p), together with biotite and hornblende and a little chlorite, graphite and pyrite. This unusual mineral association indicates the rock to be a recrystallized sediment.

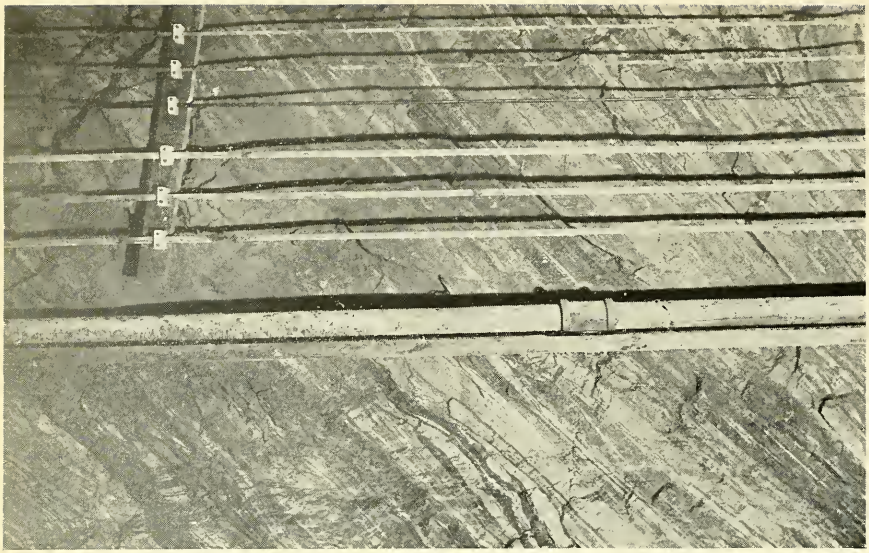
Magnification 30 ×

Pegmatite in Paxton Schist.

Such small lenticular bodies are very numerous, and are commonly grouped along the structure lines of the rock.

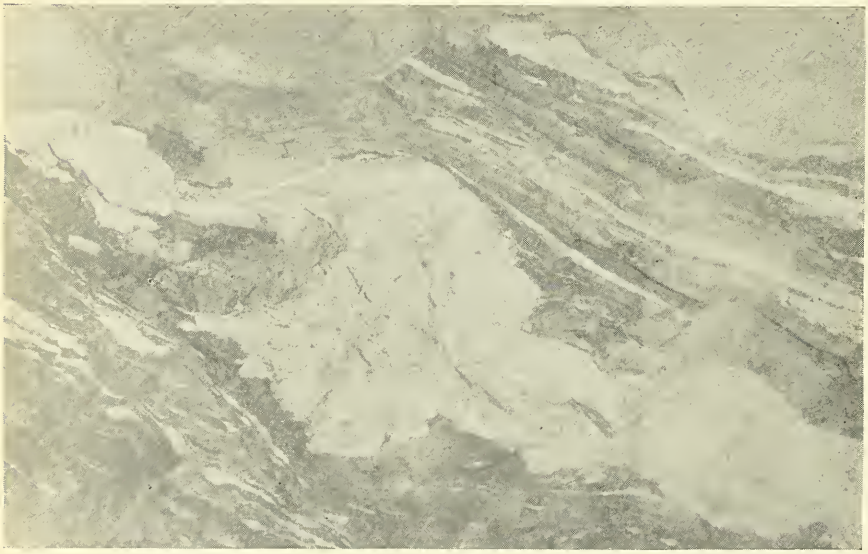
Typical Monson Granodiorite.

The dark bands which occur throughout the formation are hornblende diorite.



Banded Aspect and Structure of Monson Formation.

This view is typical of some portions of the Monson granodiorite formation where portions of unreplaced schist occur. The darkest bands are biotite schist. The lighter bands are due to variations in the amount of igneous injection and replacement.

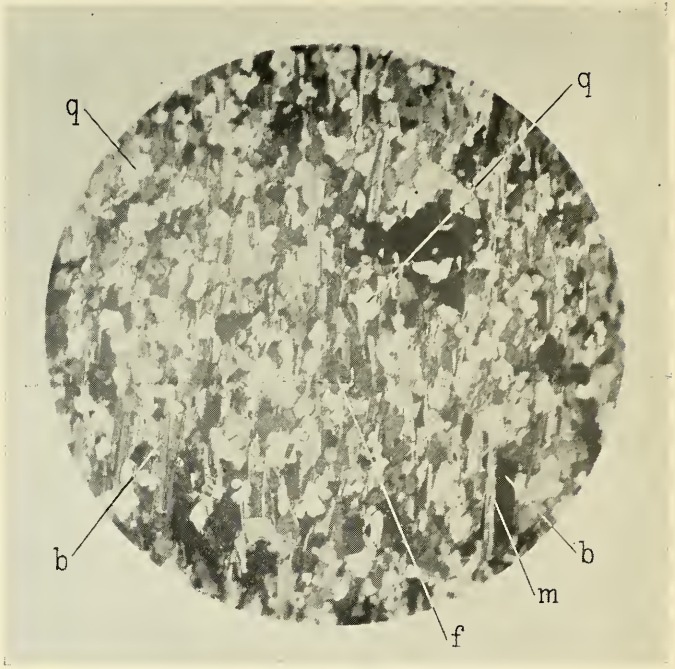


Original Sedimentary Bedding and Igneous Injection of Paxton Schist.

The narrow banding was produced by the arrangement of different layers in the original sediment and by injection of pegmatite in bands and small lenses along the foliation structure. The large irregular pegmatite body is about three feet thick.

Photomicrograph in polarized light of Monson granodiorite. The rock is of fairly simple composition, the chief constituents being quartz (q), plagioclase feldspar (p), orthoclase feldspar (o), biotite mica (b), and hornblende (h). This composition and the massive structure indicates an igneous origin.

Magnification 30 ×

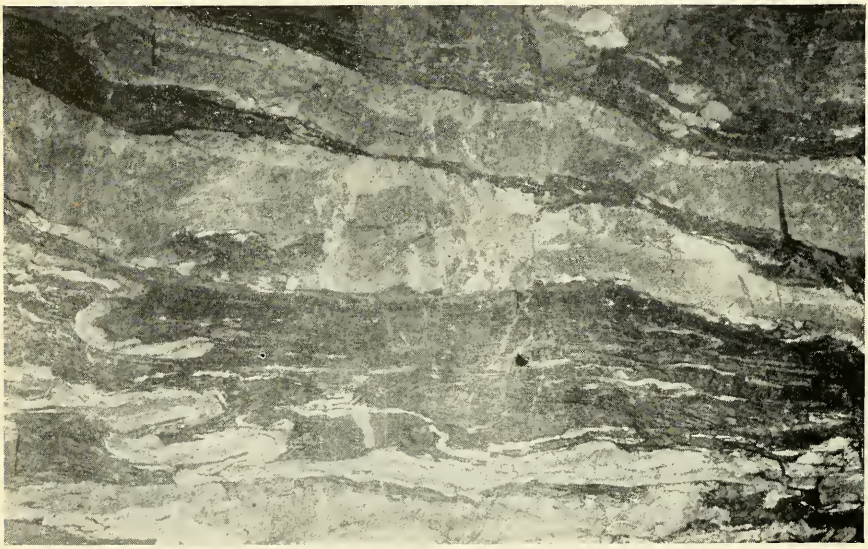


Photomicrograph in polarized light of schist remnant in Fitchburg granite. The rock is made up of abundant quartz (q) and a little feldspar (f), together with recrystallized minerals such as biotite (b) and muscovite (m). Other constituents include fibrolite, zoisite, garnet, magnetite and occasionally tourmaline. The strong foliation structure is a feature, and there is no doubt about it being a metamorphosed sediment.

Magnification 30 ×

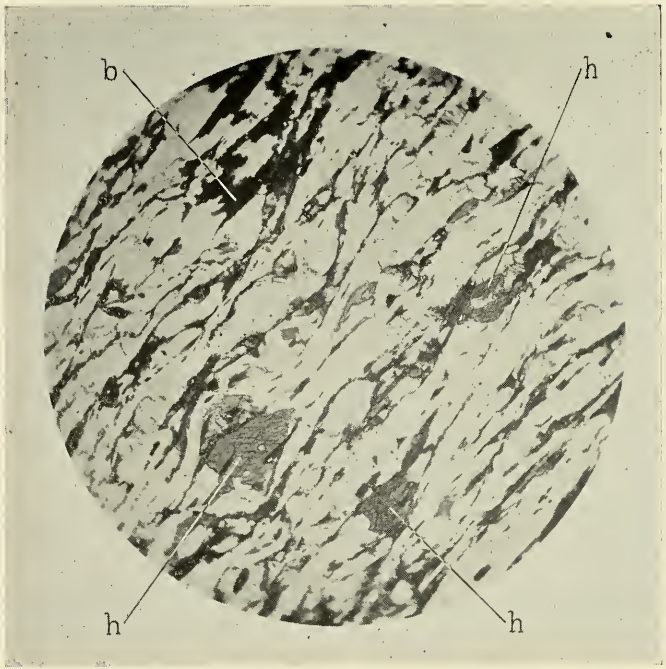
Structural Features, Gneissoid, Granite and Pegmatite in Ware Schist.

The conformity of the foliation structure in the schist and granite portions suggest that granitization was accomplished by soaking of the schist with granitic material. The dark band extending across the field is schist, above and below which the granitic constituents are abundant. There are also numerous clearly outlined lens-like patches of pegmatite.

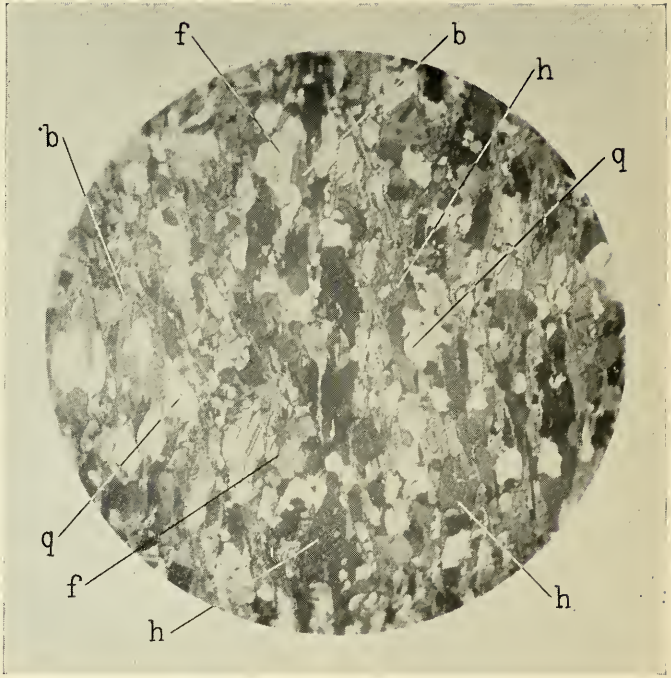


Remnants of Granitized Schist in Fitchburg Granite.

The extreme degree of igneous injection and soaking shown here is typical of a large part of the Fitchburg granite as seen in the tunnel.



Plain Light.



Polarized Light.

Photomicrographs of Paxton schist in plain and polarized light. The principal constituents are quartz (q), feldspar (f), and biotite mica (b), with titanite, magnetite, and apatite occurring as accessory minerals. The hornblende (h) and considerable portions of the feldspars, together with part of the quartz, are judged to have been introduced. The rock is a hybrid variety and is properly classed as an injection schist.

Magnification 30 ×

Permanent timber construction required to support crushed and altered rock in tunnel east of Shaft 9.

View of lined and unlined tunnel section. The rock breakage was typical of much of the tunnel.

gins of some crystals. Biotite and garnet crystals are often found embedded in a schistose groundmass made up chiefly of quartz and mica, of which about one-third of the mica content is biotite and two-thirds muscovite. There is also a small amount of albite feldspar. The larger crystals of biotite are oriented both parallel to and across the foliation or grain structure.

Numerous small lenses and bands of pegmatite and glassy quartz, as well as occasional broad vein-like pegmatite bodies, occur throughout the Boylston schist as seen in the tunnel, the quartz apparently being confined to zones of weakness, especially to shattered or crush zones. The pegmatite often contains white feldspar and glassy quartz. Quartz bands frequently contain garnet and are often associated with sulphide.

This formation was exposed in the tunnel for a distance of 1,685 feet between Stations 36+40 and 53+25. At the former location it is in conformable contact (Figure 8A) with the Oakdale quartzite, since the one grades into the other without any sharply defined boundary. The westerly limit is a sharply defined contact with a gneissoid granite, regarded as a part of the Fitchburg granite formation.

The Fitchburg Granite

The portion of the Fitchburg granite batholith occurring in a belt about 14,000 feet wide between Shafts 1 and 3 (Figures 8A and 8B) shows considerable variation in composition and structure. About 75 per cent of the rock is essentially a granite, the remaining portion being composed of extensive bodies of an older schist rock, now recognized as remnants of the former roof or cover.

The granite has a decidedly coarse texture and, due to orientation of mica flakes and frequently feldspar, it almost always exhibits a gneissoid or streaked structure. This structure is often accentuated by concentration of biotite mica in narrow bands which are generally parallel to the prevailing foliation. Sometimes the foliation appears crumpled or simulates swirls as if produced in flowage.

The mineral constituents within the granite proper vary in their proportions somewhat from place to place (Plate 4). This is particularly true of the micas, especially biotite, which is the most variable in amount. Orthoclase and microcline feldspars occur in abundance with lesser amounts of plagioclase feldspar of albite to andesine composition. Quartz and feldspar frequently occur in intergrowths. Titanite, apatite, and occasionally rutile are found as accessory minerals, and pyrite and titanite are frequently intergrown. In certain zones hornblende becomes prominent, although never dominant over biotite. The granite is essentially fresh and sound. Microscopically the rock preserves evidences of strain and shows slight fracturing.

Darker schistose portions, found mainly in the vicinity of Shaft 2, occur in several different forms; as narrow and broad bands in the granite, as irregular and sometimes sharply defined blocks, and as larger or more extensive bodies (Plate 10).

The granite frequently grades into schist through a zone that partakes of the characters of both (Plate 9). The foliation of the granite is always parallel or closely parallel to that of the schist. Throughout a large part of this granite belt the foliation structure is almost horizontal but there are zones of steeply inclined foliation especially in the easterly section where for about 4,000 feet the structure of the granite is almost vertical. At two other points farther west the structure is also very steep but there the rock is composed mainly of schist.

There is considerable variation shown in the composition of the schist bodies but in its simplest facies the rock might be classified as a quartz-biotite mica schist. Quartz and feldspar are always present in variable amounts together with the accessory minerals apatite, zircon, and titanite. Next in abundance to the quartz and feldspar constituents is biotite (often altered to chlorite), muscovite, little fibrolite, magnetite, zoisite, garnet, tourmaline, and sometimes epidote. The biotite mica is generally brownish in color in contrast to the black biotite of the granite. Whatever the rock may have been originally it is now thoroughly recrystallized. Some feldspars are partly altered to kaolin. Portions of the quartz and feldspar constituents, as well as pyrite, appear to have been introduced. Orthoclase, oligoclase and microcline feldspar, as well as

biotite mica and granular quartz occur in large amounts and some of these at least have been introduced.

Pegmatite or coarse granite occurs extensively both in the schist portions and in the simple granite areas. It occurs as veins, lenses, and bodies of irregular outline, and grades into the surrounding rock through a transition zone having fewer pegmatite constituents. Pegmatite frequently occurs as a border between blocks of schist and the surrounding granitic mass. In the more schistose zones, pegmatite frequently occurs in the form of feldspar bunches, small lenses, streaks and bands. It is also commonly found as narrow veins following the course of ancient joint structures.

The mineralogy of the pegmatite is comparatively simple, the main constituents being a white microcline feldspar and quartz with variable amounts of biotite and muscovite mica. Black tourmaline, often in association with pyrite, is found developed occasionally to rather large crystals.

The Fitchburg granite extends for 7,100 feet west of Shaft 2 to Station 191+00, at which point it is in abrupt fault contact with the Brimfield schist. This contact is now determined to be approximately 1½ miles farther east than previously mapped.[1]

The Brimfield Schist and Brimfield-Ware Schist

This formation, designated in the easterly portion of the tunnel as the Brimfield schist and in the westerly portion, for reasons to be explained later, as the Brimfield-Ware schist, occurs in several places. Its most prominent occurrence in the easterly section (Figure 8B) is for a distance of 10,290 feet from its fault contact with the Fitchburg granite to Station 293+90, a point about 600 feet east of Shaft 4. This belt is part of the east limb of a broad anticlinal or domed structure and consequently the formation does not appear again until the west limb of the anticline brings it back into the tunnel (Figure 8D) about 2,600 feet west of Shaft 8. It continues from this point, at Station 746+00, as the major rock formation throughout both headings of Shaft 9 and the east heading of Shaft 10 (Plate 5) with but the two exceptions of the Coys Hill granite and a diabase dike. At Station 973+00 it is in contact with and appears to be overlaid by the Hardwick granite formation. The Brimfield-Ware schist outcrops again in the stretch of tunnel (Figure 8F) adjacent to Shaft 11 between Stations 1132+00 and 1188+60. A similar type occurs in the extreme westerly end of the tunnel to a point beyond the portal.

The Brimfield schist is chiefly a biotite mica schist (Plate 6). In places it grades into a biotite quartzite and in other places into a quartzite with very little mica. In the easterly section of the tunnel it contains only slight amounts of garnet but in the westerly section the garnet content is high and the rock in some sections could be correctly called a garnetiferous schist. A prominent feature is the general flaky appearance due to the abundance of biotite mica and to easy separation of the rock along the foliation lines. This characteristic is accentuated by numerous irregularities caused by small pegmatite lenses. In the easterly section of the tunnel the Brimfield schist is generally of a dark reddish-brown color, whereas in the westerly section it is darker and black. Both of these color variations are due chiefly to the mica content.

The rock is always foliated and commonly has a wavy and lenticular appearance due to small lenses of quartz of only a few millimeters in diameter. Accentuated by pegmatite and quartz streaks the foliation is deformed into small steep dipping folds.

The typical schist, unaffected by addition of igneous material, contains a great deal of reddish-brown platy and occasionally fibrous biotite mica with some muscovite mica. Quartz is present mainly in microscopic lenses. Larger lenses contain also oligoclase-andesine feldspar. Red garnet is commonly, but not always, present. Mention has already been made of the high garnet content in the rocks of the westerly section of the tunnel. The needle-like mineral sillimanite or fibrolite is abundant in some sections but absent in others, as is also graphite.

Variations of the typical schist occur in definite beds and layers parallel to the

[1] Emerson, B. K., op. cit., Geologic Map of Massachusetts and Rhode Island.

general foliation or bedding. Very hard and dense quartzite types are thus found. By an increase in quartz the biotite schist grades into a biotite quartzite and with decrease of the mica content into a true quartzite. The grain size is also variable but nearly always is less than 1 mm., the average being from 0.2 to 0.5 mm. Near the larger igneous bodies or injection zones the grains become larger.

Certain varieties show complete recrystallization of the constituents and an intense foliation. Numerous large and small bodies of pegmatite and granite are present occurring both with sharply defined outlines and with transitional zones grading from one rock type into the other. These granite masses resemble in every detail the Fitchburg granite.

The Paxton Schist

The Paxton schist formation, consisting of three members, occurs throughout the central portion of the tunnel in a belt about 6 miles wide and in the vicinity of Shaft 8 in a narrower belt less than one-half mile wide. The upper member which immediately underlies the Brimfield schist of Shafts 3 and 4 extends in the tunnel (Figure 8B) for 16,530 feet between Stations 293+90 and 459+20, again (Figure 8C) for 1,080 feet between Stations 546+20 and 557+00 and again in the tunnel (Figure 8D) west of Shaft 8 for a distance of 1,000 feet between Stations 736+00 and 746+00. The lower member appears in three separated sections, from Station 476+30 to Station 522+00 for a distance of 4,570 feet, from Station 567+30 to Station 599+00 for a distance of 3,170 feet, and again from Station 722+75 to Station 731+20 for a distance of 845 feet. A middle member occurs between the upper and lower members and is considerably thinner than either of these.

The upper and lower members consist of a distinctly feldspathic quartz-biotite schist which is comparable to the Paxton quartz schist as recognized by Emerson. They are very similar in mineralogy, structure and other characteristics. The rock is commonly strongly foliated but also occurs in dense massive beds with very little foliation. In some cases the structure is made more evident by reason of a distinctly banded aspect (Plates 5, 7 and 8) produced by differences in the composition of the original sediment. A decrease in the quartz and feldspar content and consequent increase of mica creates a distinctly biotite mica variety. More massive and somewhat quartzose bands occur where there is an increase of quartz over the feldspar content. These bands are rarely over one inch thick and more often are only a fraction of an inch, especially those which are most strongly biotitic. Where there is an absence of banding the rock has a somewhat speckled appearance due to the distribution of biotite mica flakes in a groundmass of quartz and feldspar.

The most conspicuous structure indicating original sedimentary differences in composition is produced by a mineral aggregate which has a greenish-gray color, and which occurs in bands and thin lenses which average about half an inch in thickness but which may attain thicknesses of 3 or 4 inches. These are common and persistent and the metamorphic minerals of which they are now composed suggest a carbonate content in the original sediment.

The typical schist variety (Plate 11) consists chiefly of quartz, feldspar, and biotite with minor amounts of muscovite mica. The biotite is generally of a brownish or bronze color but is usually black when adjacent to pegmatite. The feldspar content is of variable grade ranging from oligoclase to labradorite but usually is of the andesine variety. In some sections numerous grains of carbonate occur as well as small amounts of garnet and zoisite.

In its general aspect the middle member of the Paxton schist resembles the Brimfield schist type. It is a distinctly more flaky biotite variety than the typical schist of the upper or lower members and as a whole contains considerably less quartz and feldspar. Despite the general resemblance to the Brimfield schist its structural association is perfectly clear and there is no doubt whatever of its designation as part of the Paxton formation as described here.

The Ware Schist

The Ware schist formation occurs in an anticlinal structure for a distance of 12,375 feet between Stations 599+00 and 722+75 (Figure 8D). It occupies

the entire tunnel between Shafts 7 and 8 and extends for a considerable distance east of Shaft 7.

The general appearance of this rock is very similar to that of the Brimfield schist but it is separated from the Brimfield formation by the Paxton formation. The dominant rock type is a dark-brown flaky biotite mica schist containing very little quartz or feldspar but commonly containing garnet, at times in sufficient quantity to be called a garnetiferous biotite schist. Interstratified beds of considerably greater quartz content occur throughout the formation. Some relatively thin layers of more feldspathic schist are also present and these sometimes contain green bands similar to those occurring in the Paxton schist. Pegmatite and gneissoid granite make up a considerable portion of the formation (Plate 10). These occur as small and large lens-shaped bodies and masses of irregular shapes with either sharp or transitional contacts.

A rather unique difference between this formation and the Brimfield is the occurrence of limestone beds which vary from 6 inches to 15 feet in thickness. These beds, found on the west limb of the anticline, are of a greenish-gray color and exhibit a perfect banded structure which is largely due to differences in grain size.

The Coys Hill Granite

The Coys Hill granite is essentially a rather extensive and prominent occurence of coarse granite within the Brimfield-Ware formation. It occurs as a conformable band or sill-like intrusion about 400 feet thick between Stations 937+00 and 946+00 (Figure 8E). Emerson[1] has mapped and described this rock type in some detail. The tunnel excavations failed to reveal anything new regarding its mineralogy and structure. There is one feature which might be emphasized however; that is the similarity of the Coys Hill granite to many other coarse granite types occurring in bands and lenses throughout the schist formations farther east.

The typical Coys Hill granite is a very coarse granite in which individual microcline feldspar crystals have developed to unusual size. These average from 1 to 2½ inches in diameter and frequently are even larger. The feldspars are so numerous and well developed in places that approximately 75 per cent of the rock is made up of large feldspar crystals or phenocrysts irregularly arranged in a darker and fine-grained groundmass of biotite mica schist. The schistose portion or groundmass, by reason of the addition of igneous constituents, is highly granitized but still exhibits a definitely streaked structure which conforms to the foliation of the over and underlying biotite schist. The coarse or porphyritic texture is due entirely to microcline feldspar, quartz being absent. Garnet, as well as fibrolite, occurs frequently throughout the rock.

The Hardwick Granite

The Hardwick granite is a conspicuous formation in the tunnel (Figures 8E and 8F) between Stations 973+00 and 1132+00. This formation is composed of several rock varieties ranging from granite to schist, the chief variety being a very dark foliated or streaked granite. This type is by far the most prominent part of the formation. It varies from a medium to coarse grain and is composed essentially of orthoclase and plagioclase feldspar and much biotite mica. The feldspars are generally present in excess of quartz. Other minerals often present are magnetite, apatite and zircon. Variations in the grain, internal structure, and mineral composition often occur which give the rock an appearance similar to a recrystallized biotite mica schist (Plate 6). Variations between schist and granite occur in the Hardwick formation which are similar to those occurring in the Fitchburg granite.

The foliation or grain structure as a whole is well developed, and is emphasized by the occurrence of light streaks and bands composed of a mineral composition consisting mainly of quartz and feldspar. In some stretches the intruded igneous rock was less affected by the older enclosing micaceous schist formation than in others. Through these stretches the rock has a decidedly massive or less foliated structure.

[1] Emerson, B. K., op. cit., pp. 240, 241.

Bands and injection zones of a light or gray granite, similar to the Fitchburg granite, which are best developed within the schistose portions, occur throughout the extent of the Hardwick formation. Small interconnected lenses of pink feldspar and glassy quartz occur, frequently resulting in giving a porphyritic aspect to the rock.

Schistose masses similar to the Brimfield schist type occur throughout the Hardwick formation. These are composed of a black mica schist in contrast to the brown mica schist formations farther east. Beds of a distinctly quartzitic schist also occur. The foliation structure of these members is prominent and regular, conforming to that of the surrounding rock. The contacts are conformable. In the lower and upper portions of the formation the typical rock is a fine to medium grained strongly foliated biotite schist containing considerable igneous material. The average variety consists of abundant black biotite mica, orthoclase and plagioclase feldspars, quartz and much garnet. The feldspars show considerable alteration to kaolin, and sericite is present. Variations in this type result from the addition of abundant apatite and the occurrence of orthoclase feldspar in greater amount than quartz. Fibrolite and graphite are often present in these schists, whereas they are always absent in the more granitic types. Thin beds of a quartzitic schist containing abundant recrystallized quartz and some plagioclase feldspar occur within the more micaceous schist types. A particular feature of the quartzitic schist is the presence of graphite and tremolite and large sprawling garnets.

The Monson Granodiorite

The Monson granodiorite occupies most of the tunnel (Figure 8F) between Shafts 11 and 12 and a large part of the Swift River Valley lying a short distance westerly. In the tunnel its exact limits are from Station 1188+60 to Station 1307+75. The typical rock (Plate 7) is a grayish foliated granite, although in some sections it is quite massive. The foliation structure is due to the concentration of biotite in streaks and narrow bands. Beds and bands of hornblende diorite, which in the majority of cases are oriented parallel to the foliation, also occur throughout its extent. In a few cases these exhibit irregular structures in which the bands have been faulted and folded.

The granodiorite of the tunnel (Plate 9) is an igneous rock of rather simple composition. It chiefly contains orthoclase and plagioclase feldspars, quartz, a little biotite mica, and considerable hornblende and magnetite. Slight amounts of garnet and sericite are also present. In some stretches schistose bands are very numerous and become the dominant feature of the rock. Light and dark colored bands are thus seen which are the result of variations in concentration of igneous constituents, the general appearance being that of an injection gneiss. The schist portions are essentially unreplaced remnants of the former cover and to all appearances are related to the Brimfield-Ware formation (Plate 8).

The dioritic rocks are made up largely of abundant hornblende, considerable plagioclase feldspar, and minor amounts of magnetite, biotite, titanite and apatite. The rock is frequently of a massive structure, especially where it forms a contact zone between the Monson granodiorite and the Brimfield-Ware schist formation. Emerson[1] has called this particular variety the Dana diorite.

A pale reddish or pink variety of granite intrudes the gray Monson granodiorite at several points. The best example of this occurs as a sill-like body or sheet east of Shaft 12. The outer portions of this body are of medium to coarse grain. The adjacent wall rock is peculiarly spotted by reason of the scattered reddish orthoclase feldspar crystals in the gray granite. The inner portions of this intrusive mass are of much coarser grain than the outer, some feldspar crystals being several inches in diameter. The whole rock has undergone transformation in which the feldspars have been greatly altered to a clayey constitution and partly replaced by quartz. Upon excavation this material was seen to be composed of gray to reddish clay surrounding angular blocks of quartz. When exposed to the elements the unreplaced but completely altered feldspars in these blocks were easily weathered and the clayey material washed away. Because of the instability of this rock it was necessary to support the tunnel

[1] Emerson, B. K., op. cit., p. 244.

roof and sides by erecting timbering and providing for greater thickness of concrete lining. The phenomenon presented here is similar to the Lantern Hill quartz replacement in southeastern Connecticut described by Loughlin.[1]

A large remnant mass of schist approximately one-half mile wide divides the Monson formation into two parts. The rock is a medium-grained strongly foliated biotite schist frequently containing small beds of amphibolite schist. The average schist contains much biotite mica as well as acid plagioclase and quartz. Garnet, titanite and apatite minerals are also present. Streaks and bands of feldspar-quartz composition are as prominent here as in the schist formations elsewhere.

Diabase

Tunnel excavations were carried through two diabase or trap rock dikes, one of which occurs between Shafts 3 and 4 (Figure 8B) and the other between Shafts 8 and 9 (Figure 8D). These dikes, which have been traced for several miles beyond the immediate vicinity of the tunnel, cut across the area in a nearly parallel northeasterly direction. They are offshoots of the much larger diabasic intrusions of Triassic age occurring within the Connecticut Valley area.

The Mixed or Hybrid Rocks

The formations of the tunnel area seldom occur in a simple condition. They vary from true schists, derived by the metamorphism of sediments, to gneissoid granites and pegmatites, clearly of igneous origin. Traces of material, more or less clearly defined, and resembling the original schists are nearly always associated with the granitoid masses. As a matter of fact, between the two extremes of granite and schist there are all gradations which appear to be mixtures of these two primary types.

Examination and critical inspection of these formations in the tunnel suggests their classification as mixed or hybrid rocks. The field relations of the different original sedimentary formations were surely favorable for the invasion of granitic and pegmatitic juices from an igneous body encroaching upon them from below. If it were ever possible for igneous material to penetrate rocks of a schist type it should have happened under these conditions. Originally there were extensive bodies of sediments developed into schists with a strong foliated structure in which penetrating solutions could find many weaknesses along which to move in attempting to escape or break through. Such a process, involving a highly penetrative invading solution, ought to produce all of the varieties of structure and proportions between simple schist on the one hand and true granite or pegmatite on the other. This is exactly what is found in the tunnel and there appears to be no other way of accounting for them.

The main bodies of the Fitchburg granite and the Monson granodiorite contributed a large part of the invading solutions. All of the formations of metamorphic character developed antecedent to the igneous invasion have been affected to some degree dependent upon their distance from the igneous sources of supply and on their differences in primary composition and metamorphic structure.

The deformations existing at the time of the igneous intrusion appear to have determined the results and to some extent to have directed the major movements. It should have been possible for the granitic juices or magma to penetrate readily along clear-cut fractures or fissures developed by deformations, thus forming the larger dikes and other transecting masses of simple composition. The more intimate mixtures of constituents, characteristic of both the schists and the granites could not have been produced without actual mixing of the two types of rock in some manner or the replacement of a portion of one by a portion of the other.

The mixed product which occurs in one form or another throughout long stretches of the Quabbin Aqueduct, presents many facies and every possible proportion. The introduced igneous material is so intimately interspersed and interlocked with the recrystallized sediments that it is quite impossible to dis-

[1] Loughlin, G. F., The Gabbros and Associated Rocks at Preston, Conn., U. S. G. S. Bulletin 492, 912.

tinguish clearly between them and to determine their relative proportions. It is, however, usually possible to identify the two major elements of the mixture. The common facies is, therefore, a hybrid rock that is properly called an injection schist.

The clearly recognizable igneous bodies occurring in these schists are found in several modes of occurrence and with wide range in size as follows: feldspar bunches, knots, or lenses which often consist of single crystals or a simple aggregate of feldspar crystals; thin lenses and bands of pegmatite producing a typical banded injection structure. There is sometimes associated with this type an intimate intermixing with the schist; large lenticular bodies of pegmatite varying in size from a few inches to several feet in diameter; sill or sheet-like bodies which often attain sizes as great as 50 feet or more in thickness; irregular but generally lenticular-shaped bodies containing pegmatite and gneissoid granite.

The contacts between these igneous bodies and the older schist members are either sharply defined or gradational from one type to the other. On a large scale the foliation of the schist is bent around the igneous bodies indicating that at least a part of the space required for the intrusive pegmatite was made by actual displacement of the schist. Embayed contacts, however, and truncation of the foliation structures indicate that the larger part of the space required was made by replacement of the schist. Gneissoid granite grades into the schist through a zone of mixing and banded injection as if the granitic solutions had soaked into the surrounding schist and penetrated almost every interstitial weakness.

Pegmatite is often uniformly distributed along the foliation planes of the biotite schist but its concentration varies greatly from place to place, the greatest concentrations being found in the biotite schist formations. In the Ware schist formation, for example, for a distance of 1,000 feet between Shafts 7 and 8, there occurs gneissoid granite which is certainly almost wholly igneous, and for a considerably longer stretch the amount of injection is very heavy (Plate 10). The concentration of pegmatite within the Paxton schist is considerably less than in the more micaceous varieties (Plate 7). In the more quartzose schist members the amount of pegmatite is negligible, although the beds are cut by quartz veins.

The principal constituents of the most widespread pegmatite, responsible for the development of mixed and hybrid rocks, are microcline and quartz. This pegmatite is always white, while the less notable pegmatite, more abundantly developed in the Hardwick and Monson granites, is of a reddish color. Albite and oligoclase feldspar are present in variable proportions. The plagioclase feldspars are often partially altered but microcline feldspar is nearly always clear and fresh. In the larger bodies feldspar is considerably more abundant than quartz but in the narrow bands and lenses, especially in the end sections of elongate lenses, the main constituent is glassy quartz. Both muscovite and biotite mica are generally present as accessory minerals. Garnet is prominent in the pegmatites occurring within the distinctly garnetiferous schists. Black tourmaline is common throughout the Paxton schist of Shafts 4 and 5. Other variations in composition are due to the presence of schist inclusions and to concentration of biotite in streaks parallel to the foliation. Sericite, together with chlorite, is an abundant alteration mineral. Large sections of granite are strikingly fresh with almost no evidence of alteration, whereas the dusty appearance of orthoclase and plagioclase feldspars in contrast with the freshness of the microcline feldspar is very noticeable. Large grains occasionally show granulation along their margins and the softer minerals, chiefly mica, have developed along the weaknesses. Garnet is often present in large amounts and is believed to indicate assimilation of some other rock.

Portions of the gneisoid granites represented within the injection schists possibly are not all of the same origin. It is believed, however, that a large portion of the streaked rocks had their origin through a process of extreme granitization of the overlying and adjacent schist.

Granitization of Schist Bodies

The presence and mode of occurrence within the tunnel area of numerous and extensive bodies of schist mapped as Fitchburg granite raises the question of origin of the granite itself. Was it formed, as most granites are believed to have been, by simple crystallization of an igneous material or magma, or is it, instead, a mixed and variable product made up in part of simple introduced or eruptive magma and in part of absorbed masses of older rock? The mode of occurrence of these schist bodies seems to have a bearing on this question. These masses are so uniform in orientation and their internal structure matches so well that they give the very definite impression of having been but little disturbed. As previously stated, most of the contacts are gradational in character and the foliation structure of the granite is essentially continuous and consistent with that of the nearby schist bodies.

A close genetic relation is indicated between the streaked structure of the granite mass and the foliation structure of the schist, which suggests that the structure seen in the granite may have been inherited from the schist. This could happen if a mass of schist were so thoroughly granitized that more than three-fourths of its volume was composed of granitic constituents. It could happen also if a schist body were digested and absorbed by an invading granite without complete redistribution of the constituent elements. In this case the micas would still remain in part in the same general structural relation. Both processes are believed to have operated in some of this material and caused the streakedness within the granite.

A large portion of the Fitchburg granite preserves, somewhat crudely to be sure, the structure of the schist which originally occupied the same place. In other words, the foliation in the granite is chiefly an inherited structure which marks the major structure lines of the schist masses that were invaded, absorbed and replaced (Plate 10). It is realized, of course, that some of the streaked structure is probably due to movement of the granite mass after crystallization had begun, although these movements seem to have followed the chief lines of deformation in the invaded rock series.

The general deformation of the region, preceding the granite invasion, may be worked out from these inherited structures. A study of the field occurrence of the two rock types, schist and granite, together with their structure, mineralogy and gradational features, suggests several stages in the formation of the granite which are here summarized.

Before the invasion of the granite the geologic column was represented by a thick series of rocks consisting partly of the Brimfield-Paxton-Ware series. Deformation of these sediments was accompanied by, or closely followed by, encroachment of a large granitic body. Advance of the highly fluid granitic magma or rock solution was greatly facilitated by certain zones of weakness developed by this deformation, especially in the area between Shafts 1 and 2, where there is preserved even now a strong vertical or down-folding in the granitic structure. It is here that granitic soaking and injection was most intense as indicated by either displacement or complete granitization of the original rock. Facilitating this process was the breaking, from the lower members of the rock series, of blocks which foundered and were more or less completely absorbed in the granitic magma. This process, accompanying continued down-folding and faulting, created the main channel for encroachment of the granite magma. Further extension of the invasion was accomplished largely by lateral penetration and soaking. Numerous smaller feeders from below distributed over a large area must have added greatly to the supply of magma.

Small openings and potential weaknesses in the strongly foliated rock provided sufficient space for the highly fluid feldspathic magma which worked its way into the schist both by this means and by a gradual process of replacement. Thus there were developed multitudes of small feldspar and quartz lenses as well as thin streamers made up of mineral aggregates of the same composition, all of which have been described in more detail elsewhere in this report.

In the earlier stages the biotitic aspect of the rock was dominant over the feldspathic and the appearance must have been similar to a banded or injection schist or gneiss. Further injection and soaking increased the igneous content

until these constituents were dominant over those of the original schist. This theory is supported by the occurrence within the granite of schist exhibiting essentially all of these features. Remnants of the schist can be seen accurately oriented and unreplaced grading into completely granitized rock with only traces of the same orientation.

In a more advanced stage the rock was completely granitized and appeared as a slightly foliated and sometimes even massive biotite-muscovite mica granite. It is possible also that large portions of the present granite masses originated from direct crystallization of the invading magma, but granitization of the older rock is believed to account for equally large proportions.

The less extensively granitized and injected bodies of schist associated with the granite represent the more dense and massive beds such as the quartzitic varieties interbedded with the original biotite schist. The pore space in such rock was comparatively small, and beds of this massive type yielded very little during deformation, so that slight opportunity was provided for the granitic juices to work their way into these portions.

Structural Features

A great variety of internal structures are exhibited by the rocks. Some of these structures are due to igneous injection and have been described elsewhere in this report. Others, such as bedding and sedimentation lines, are original. Still others are of metamorphic origin and raise questions as to the conditions and processes that could have produced them. Of these structures the most characteristic is that of foliation, which is developed throughout the schists and a large part of the granite formations.

Foliation and Bedding

In the construction of a geologic section to show the relation of the formations penetrated by the tunnel special attention was paid to all structural features which might have a bearing on the relation of foliation to original bedding. The close parallelism found to exist between original bedding or sedimentation lines and the present foliation must be the result of subsequent metamorphism. This conclusion has also been reached by others[1] who are familiar with the formations in central Massachusetts and their counterparts in eastern Connecticut.

The bedding planes of the small but distinguishable interbedded layers, composed of different mineral quality, are parallel to the present foliation structure of the schists. This is true of the micaceous and quartzitic beds in the Brimfield, Ware and Brimfield-Ware formations, of the limestone beds in the Ware schist, and the garnetiferous beds in the Brimfield-Ware schist and of the thin micaceous and calcareous layers and streaks in the Paxton formation. A graphical check of the general conformity of the bedding and foliation structure, obtained by plotting the inclination of the foliation lines as if they were true bedding planes, showed a general conformity between the boundaries of the several formations and the expected general structure.

In the recrystallization of such great bodies of schist it is rather striking that the foliation structure should conform so closely to the original bedding of the sediments from which they were made. This is surprising because of the flat-lying attitude of these formations throughout long stretches of the tunnel. It is difficult to see how this condition could have resulted if recrystallization of the schists were due chiefly to intense metamorphism resulting from the strains induced by deformation. The gentle folding of the whole rock series over extensive areas could have accounted for only a small amount of differential internal movement. The recrystallization of the schists is believed to have been caused more by the metamorphic action of subjacent and invading igneous bodies, than by metamorphism resulting from movement or regional deformation.

[1] Callaghan, E. C., A Contribution to the Structural Geology of Central Massachusetts, Annals of the New York Academy of Science, Vol. 33, pp. 43–46.
Rice, Wm. North, and Gregory, Herbert E., Manual of the Geology of Connecticut, State of Connecticut, Geological and Natural History Survey, Bulletin No. 6.
Loughlin, G. F., The Gabbros and Associated Rocks at Preston, Connecticut, U. S. G. S. Bulletin 492, 1912, pp. 24–25.

Thickness of Formations

Data pertaining to the measurement of formations is of interest to both the geologist and the engineer. To the geologist such information is essential to the grouping of rocks into formational units and to an understanding of the geology of a region. The solution of problems pertaining to correlation of the formations in one area with those in another, and to the interpretation of the deformation and structure of formations is also partly dependent upon such data. In a glaciated region, such as central Massachusetts, underlaid by metamorphosed igneous and sedimentary rocks, it is often difficult to obtain even an approximate estimate of the formational thicknesses.

The excavations exposed several formational contacts which were located accurately, thus defining the extent of the rock formations in the tunnel, and, by construction of the geologic section shown in Figure 8, the thicknesses of the several formations were estimated. The estimates of the Paxton formation are considered to be particularly reliable as all four contacts of the three members were located. Inaccuracies in estimates of this kind may be due to several causes, chief of which is the uncertainty of the amount of increase or decrease in the thickness of strata resulting from folding and faulting.

A significant feature of the geologic section is the marked decrease in thickness of the Paxton formation from east to west. The fact that the Paxton schist was not again recognized in the tunnel for the remaining eleven miles is not surprising as the great amount of igneous injection in several stretches farther west, especially in that of the Coys Hill granite, could have changed the appearance of the formation beyond recognition. In this connection it is of interest to note that Emerson[1] considers the Quabbin quartzite, outcropping farther west in the Swift River Valley, as the equivalent of the Paxton schist.

The term "apparent thickness" in the tabulation of thickness of formations shown below means the thickness of the formations from one formational boundary to another. This measurement does not take into account variations produced by folding and faulting. By "actual thickness" is meant the estimated extent of the original formation when its deposition as a sediment was completed.

Lateral Extent and Estimated Thickness of Formations

Formation	East Contact Station	West Contact Station	Length Exposed in Tunnel Lin. Ft.	Apparent Thickness in Tunnel Ft. (Approx.)	Actual Thickness Ft. (Approx.)	Remarks
Worcester phyllite	—	—	0	—	1,600	Not exposed in tunnel.
Oakdale quartzite	—	36+40	1,542	800	1,800	Not fully exposed in tunnel.
Boylston schist	36+40	53+25	1,685	800	—	Truncated by Fitchburg granite formation.
Fitchburg granite	53+25	191+00	13,775	—	—	
Brimfield schist	191+00	293+90	10,290	2,000	Less than 3,000	Fault contact with Fitchburg granite at Sta. 191+00.
Paxton schist (upper member)	293+90	459+20	16,530	1,100	1,100	
Paxton schist (middle member)	459+20	476+30	1,710	400	400	
Paxton schist (lower member)	476+30	522+00	4,570	—	—	Lower contact not exposed.
Paxton schist (middle member)	522+00	546+20	2,420	400	400	
Paxton schist (upper member)	546+20	557+00	1,080	—	—	Upper contact not exposed.
Paxton schist (middle member)	557+00	567+30	1,030	400	400	
Paxton schist (lower member)	567+30	599+00	3,170	1,100	1,100	

[1]Emerson, B. K., op. cit., p. 72.

Lateral Extent and Estimated Thickness of Formations — Continued

Formation	East Contact Station	West Contact Station	Length Exposed in Tunnel Lin. Ft.	Apparent Thickness in Tunnel Ft. (Approx.)	Actual Thickness Ft. (Approx.)	Remarks
Ware schist	599+00	722+75	12,375	3,000	Less than 3,000	Contains many igneous masses.
Paxton schist (lower member)	722+75	731+20	845	450	450	
Paxton schist (middle member)	731+20	736+00	480	175	175	
Paxton schist (upper member)	736+00	746+00	1,000	290	290	
*Brimfield-Ware schist	746+00	937+00	19,100	5,100	—	
*Coys Hill granite	937+00	946+00	900	400	—	
*Brimfield-Ware schist	946+00	973+00	2,700	900	—	
*Hardwick granite gneiss	973+00	1,132+00	15,900	4,000	—	
*Brimfield-Ware schist	1,132+00	1,188+60	5,660	3,100	—	
*Monson granodiorite	1,188+60	1,307+75	11,915	7,500	—	
*Brimfield-Ware schist	1,307+75	2,800 ± ft. west of portal	—	2,600	—	

* Actual thickness not estimated because of possible repetition of strata resulting from folding and faulting.

Folds and Faults

The geologic structure over long stretches is comparatively flat and strikingly little folded for such intensely metamorphosed schists. The most pronounced deformations occur in the Fitchburg granite belt and in the westerly portion of the tunnel. As stated previously, the foliation structures of the granitic rocks are inherited from the older schists which were invaded by granite.

It is rather remarkable that so little major faulting was recognized in the belt crossed by the tunnel. Many minor structures indicate that there has been faulting and it is certain that the district has been considerably deformed, but ordinary evidences of faulting have been obscured or entirely obliterated by igneous intrusions. It is believed that where faulting has taken place the displacements in most cases were relatively small, and, in the easterly section of the tunnel, at least, were insufficient to displace an entire formation. This contention may not hold, however, for the westerly portion of the tunnel.

In order to reconcile the distribution of the middle member of the Paxton schist it was necessary to place two faults in the geologic section east of Shaft 8, one of which was located in a break that is now occupied by a rather large intrusion of pegmatite. This location was indicated by slight differences in the character of the rock on either side of the pegmatite. The second fault was located nearer the shaft at a point where shear structures and inclination of the strata gave evidence of faulting. Both of these faults are of slight displacement and are virtually negligible as structural features.

As noted previously, the contact of the Fitchburg granite with the Brimfield schist east of Shaft 3 is abrupt and sharply defined. On the east side of a shear and crush zone the normal granite occurs together with granitized schist, and on the west the Brimfield schist occurs with only small amounts of igneous injection. Within the crush zone there are several narrow quartz veins carrying structural evidence of normal fault movement in which the west, or Brimfield schist side, has been displaced downward. Here again the amount of displacement is judged to be comparatively small.

Estimates of the actual thickness of the formations west of Shaft 8 have not been submitted because of the uncertainty in regard to folding and faulting. Difficulties arise in the separation and assignment to their formations of several biotite schist strata, which occur throughout the tunnel between Shafts 9 and 12, because of their similarity to each other and to the Brimfield and Ware schist formations farther east. Consequently, the name Brimfield-Ware schist has been applied to these doubtful formations. Emerson assigned these schists to the Brimfield formation but it may be noted that he was not aware of an addi-

tional biotite schist formation designated as the Ware schist. The schists east of Shaft 10 and in the vicinity of Shaft 11 are of a higher garnet content and darker color than the less garnetiferous brown Brimfield schist east of Shaft 4 and between Shafts 8 and 9. Because of their garnet content the garnetiferous schists of the Ware-Brimfield formation are believed to be more closely related to the Ware formation than to the Brimfield formation.

The continuous westerly dip of the foliation between Shaft 8 and the portal may be due to closed or isoclinal folds overturned toward the east. The westerly dip of the foliation structure of schist strata within the Hardwick granite and Monson granodiorite is not at variance with this interpretation as the structure in these formations has been inherited in much the same manner as in the Fitchburg granite. Some of the streaked structure in these rocks may be due to movement of the igneous mass during and after crystallization, but these movements followed the chief lines of deformation in the invaded rock series.

The geologic section through the metamorphosed sediments, west of the main body of Wachusett Reservoir and east of the Stillwater River, where the structure is too plain and simple to be questioned, shows a simple anticlinal and synclinal structure in which a phyllite conformably overlies a phyllitic quartzite. This relation was found long ago by Emerson and Perry,[1] who mapped the phyllite as the Worcester phyllite and the phyllitic quartzite as the Sterling quartzite, which was later named Oakdale quartzite by Emerson. Completion of the section between the Stillwater River and Shaft 2 involves several possible interpretations of the geologic structure, a discussion of which follows.

Age and Formational Relations

An understanding of the structural and metamorphic relations of the Worcester phyllite and Oakdale quartzite, as recognized by Emerson, to the schists in the areas farther west requires a review of the discussions pertaining to the age relations and genesis of these rocks as given by previous workers in this field. Emerson and Perry,[2] with the cooperation of David White, have established the age of the Worcester phyllite at its type locality, the Worcester "Coal Mine," as Carboniferous, and because of its conformable relation with the Oakdale quartzite, they have concluded that the quartzite also belongs to the Carboniferous. Emerson[3] states that "The Worcester phyllite is Carboniferous, for it contains Lepidodendron and several species of ferns at the Worcester 'coal mine.' . . . The Oakdale grades into the overlying Worcester phyllite by an easy transition, without visible unconformity or interruption. . . . The conclusion that the Oakdale quartzite is of Carboniferous age is greatly strengthened by the fact that it and the Worcester phyllite are closely folded together. . . . Another reason for believing that the two formations belong to the same geologic period is that they are cut by the same set of igneous rocks."

Emerson considers that the Brimfield and Paxton schists are also of Carboniferous age and contends that the former is simply the metamorphic equivalent of the Worcester phyllite, the Boylston schist being an intermediate type between the Worcester and the Brimfield, and that the Paxton is a metamorphic equivalent of the Oakdale quartzite. He further states[4] "The reason for extending the Carboniferous area to include the highly altered rocks that are correlated with the Oakdale and Worcester is that, even though those rocks are much more metamorphosed, every effort to find boundaries separating them from the less altered rocks of undisputed Carboniferous age in the Worcester area has failed. . .

". . . not only does the great increase of granite northeastward and westward from the Worcester area furnish a sufficient explanation for the increased metamorphism of the sedimentary rocks, but also the metamorphism is just the sort that such granite should produce. . . ." It is now intended to test this opinion in the light of new and more complete geologic information obtained by study of the rock formations penetrated by the Quabbin Aqueduct. The chief elements involved will be given in the form of alternative interpretations of the struc-

[1] Perry, J. H., and Emerson, B. K., The Geology of Worcester, Mass., 1903, p. 43.
[2] Perry, J. H., and Emerson, B. K., op. cit., p. 29.
[3] Emerson, B. K., op. cit., p. 77.
[4] Emerson, B. K., op. cit., pp. 77–78.

tural attitude of the formations. The first three of these have already been presented by Callaghan.[1]

INTERPRETATION I — BASED ON EMERSON'S CONCEPTION OF EQUIVALENCE OF FORMATIONS

Assumptions — Simple Structural Relation

All of Carboniferous Age

Brimfield Schist	= Boylston Schist	= Boylston Schist
Upper Paxton Schist	= Phyllitic Quartzite	= Phyllitic Quartzite
Middle Paxton Schist	= Phyllite	= Worcester Phyllite
Lower Paxton Schist	= Quartzite	= Oakdale Quartzite
Ware Schist	= ?	= ?

This interpretation is based on Emerson's view that the Paxton and Brimfield schists are metamorphic equivalents of the Carboniferous Oakdale quartzite and Worcester phyllite, and that the simple types of the Worcester strata grade into the more complex metamorphic types of the areas to the west. Emerson was not aware of the fact, which has now been established, that the schists west of the Worcester strata occur in more than two formations, that the Paxton schist is composed of three members, and that the Brimfield type occurs in two thick formations, called here the Brimfield schist and the Ware schist. Figure 9 shows the geologic section based on this hypothesis of equivalence of formations. In the section the phyllite, or presumed Worcester phyllite, is shown as grading into the middle member of the Paxton schist, and the quartzite, or presumed Oakdale quartzite, as grading into the lower member of the Paxton schist.

The Brimfield schist of Shaft 3 is carried through the granite area of Shaft 2, the foliation of the latter being considered as inherited from the original structure of the schist. The Boylston schist is correlated, then, with the lower part of the Brimfield.

Although this is one of the simplest explanations, there are difficulties in its acceptence at full face value, just as there are in all of the simpler explanations assuming equivalence of the two sets of formations. It should be stated that this structural interpretation, with the single exception of the equivalence of formations, does not conform to the ideas of Emerson and Perry, who concluded that the structural relations of the rocks are more nearly like those presented in Interpretation III, shown graphically in Figure 11. The great resemblance, in some respects, of the schists to more ancient rocks has led to consideration of alternative hypotheses given as the last three of the group.

INTERPRETATION II — BASED PARTLY ON EMERSON'S CONCEPTION OF EQUIVALENCE OF FORMATIONS

Assumptions — Repetition of Strata by Faulting

All of Carboniferous Age

Brimfield Schist	= Boylston Schist	= Worcester Phyllite
Upper Paxton Schist	= Phyllitic Quartzite	= Oakdale Quartzite
Middle Paxton Schist	= ?	= ?
Lower Paxton Schist	= ?	= ?
Ware Schist	= ?	= ?

This interpretation is based partly on the premises of the previous one, that the schists of the tunnel are the metamorphic equivalents of the Carboniferous Worcester phyllite and Oakdale quartzite. The distribution of rock types, as revealed from surface exposures, indicates a narrow strip of phyllite between the quartzite of the anticline and the phyllitic quartzite of the tunnel adjacent to Shaft 1. This repetition of strata, as indicated in Figure 10, could be brought about by a normal fault in the valleys now occupied by the upper part of the reservoir, Stillwater River and Malden Brook.

INTERPRETATION III — BASED PARTLY ON THE CONCEPTION OF EMERSON AND PERRY OF THE EQUIVALENCE OF FORMATIONS

Assumptions — Repetition of Strata by Folding

All of Carboniferous Age

Brimfield Schist	= Boylston Schist	= Worcester Phyllite
Upper Paxton Schist	= Phyllitic Quartzite	= Oakdale Quartzite
Middle Paxton Schist	= ?	= ?
Lower Paxton Schist	= ?	= ?
Ware Schist	= ?	= ?

This interpretation is based upon the conceptions of Perry and Emerson[2] that the Brimfield and Paxton schists are metamorphic equivalents of the Carbon-

[1] Callaghan, E., op. cit., p. 70.
[2] Perry, J. H., and Emerson, B. K., Geology of Worcester, 1903. pp. 148–149.

iferous Worcester phyllite and Oakdale quartzite, and also that, west of the Oakdale arch or anticline, these strata occur together in closed and partly overturned folds. A development of the structure from this premise would correlate, therefore, the Worcester phyllite with the Boylston and Brimfield schists, and the Oakdale quartzite with the phyllitic quartzite of the tunnel and the upper Paxton member. Such an interpretation would mean that the narrow strip of phyllite on the west limb of the anticline is an intensely squeezed portion or syncline of the Worcester phyllite. Minor folds and fault structures within the phyllite and quartzite indicate a thrust action from the west. This is further indicated by the minute folding and crumpling of the phyllite and by the minor overthrust relations found at a few points in exposures located along the north shore of the Wachusett Reservoir.

This alternative interpretation, shown in Figure 11, and originally presented by Emerson and Perry, appears to satisfy the structural requirements as fully as any, if the basic assumptions of geologic age and correlation of formations are correct.

Dissenting Views Concerning Geologic Age and Genesis of the Schists

Geologists, who have studied the geology of this area in the field, are not in agreement as to the age relations of the uncertain schists and the proven Carboniferous phyllite. East of the Worcester sediments there occurs a belt of injection gneisses and schists containing masses of Paxton and Brimfield schist and composing a formation referred to by Emerson as the Bolton gneiss. Regarding the principal parts of this formation he states[1] ". . . the Oakdale quartzite and Worcester phyllite formerly extended eastward over the area . . . the 'Bolton' gneiss and associated rocks as a whole . . . represent those formations, folded and partly metamorphosed to the Paxton and Brimfield schists, and . . . form the cover, now greatly eroded, . . . into the lower part of which the Andover granite was intruded.

". . . therefore, the whole complex . . . (except, possibly, a few small included masses of limestone) . . . is of Carboniferous age.

"Messrs. Keith and LaForge, on the other hand, have come to a radically different conclusion. . . . They agree . . . in believing the Andover and Ayer granites to be of late Carboniferous or post-Carboniferous age, . . . and in the view that the 'Bolton' gneiss represents a folded cover . . . into which the Andover granite was intruded, and that the intrusion was in part contemporaneous with the latest folding of the rocks.

"They doubt, however, that the Worcester phyllite and Oakdale quartzite ever extended eastward to any great distance over the area occupied by the gneisses . . . that the chemical and mineral composition of the 'Bolton' gneiss is sufficient evidence to warrant the conclusion that it was derived from a rock like the Brimfield schist; and that the Paxton schist, or at least a great part of the rock so mapped, was ever derived from the Oakdale quartzite by any kind of metamorphism. . . .

"They believe that the sedimentary part of the unnamed gneisses and schists is very much older than Carboniferous and probably pre-Cambrian; that the much deformed and sheared associated igneous rocks . . . are very much older than the Andover and Ayer granites and are also probably pre-Cambrian; and that the whole complex was first folded . . . probably in pre-Cambrian time, at any rate long before the deposition of the Carboniferous strata or the intrusion of the younger granites.

"The principal facts . . . on which they base their conclusions as to the age of the rocks are as follows: the strong resemblance . . . of some of the . . . schists to rocks in other parts of the State which are generally admitted to be probably pre-Cambrian; the greater deformation, greater alteration . . . and the general appearance of greater age of the sedimentary schists as compared with strata that are undoubtedly Carboniferous . . . and the fact that a great part of the deformation and alteration of the . . . gneisses and schists appears to antedate the deposition of the Carboniferous strata and the intrusion of the younger granites."

[1] Emerson, B. K., op. cit., pp. 86–89.

The evidence indicates that the schist formations of the tunnel represent the metamorphic facies of an ancient series of sedimentary rocks, and that, after a long interval of time, the Carboniferous strata were unconformably laid down upon them. This view is in agreement with Messrs. Keith and LaForge. Conclusive proof of any particular theory is lacking. When the Quabbin project was begun it was thought that construction of the tunnel would surely solve this geologic riddle for it transects the disputed zone where one rock series was supposed to change into the other. Unfortunately, despite the fact that this ground was laid open to view and was subjected to inspection inch by inch for many miles, the case is still a subject for interpretation rather than direct observational proof, principally because the Fitchburg granite has invaded the critical zone where such a change would have taken place and appears to have destroyed the evidence.

INTERPRETATIONS IV AND V — BASED ON CONCEPTION OF DIFFERENT AGES

Assumptions — Different Ages, Thrust Faulting and Igneous Invasion

* * * * * * *	= Igneous invasion (Fitchburg granite)	Late Carboniferous Age
# # # # # # #	= Overthrust fault	
Worcester phyllite	= Boylston schist	Carboniferous Age
Oakdale quartzite	= Phyllitic quartzite	
- - - - - - - -	= Unconformity	
Brimfield schist	= ?	Pre-Carboniferous Age
Paxton schist	= ?	
Ware schist	= ?	

These two interpretations assume that the Paxton, Brimfield and Ware schist formations represent an ancient series of rocks which were somewhat metamorphosed and deformed before the much younger Carboniferous strata were laid down. These younger rocks were unconformably deposited on an eroded surface which cannot now be traced. The whole double series of formations was then folded and faulted after which the Fitchburg granite invaded the deformed rocks and destroyed most of the structural evidence of these steps. In this view the Fitchburg granite mass occupies the disturbed ground where at one time the older crystalline schists were thrust up and over the younger sediments.

The presence of schist remnants in the tunnel for several hundred feet west of the Fitchburg granite-Boylston schist contact is not at variance with this interpretation and may support it. The foliation in the granite, and that of the included bodies of schist, is steeply inclined throughout the adjacent section. This structure has been interpreted as the inheritance of a down-drag or fold in the original roof or cover formed by the Brimfield schist. After the Carboniferous sediments had been deposited the rocks were folded and finally faulted, the younger sediments being ultimately crowded over and forming local folds. During the latter stage of deformation the thrust further developed the downfold in the Brimfield schist and the simultaneous invasion of the granitic magma from below further weakened the strata and tended to obscure and destroy the structural detail. Either one of the two structures shown in Figures 12 and 13 could have developed under these conditions. Under one alternative the younger sediments were deformed into closed or isoclinal folds in which no further release from strain was possible and over which the Brimfield schist was thrust. This possibility is indicated by Figure 12. Under the other alternative isoclinal folds developed in both the ancient and younger strata, which were finally overturned, and two thrust faults developed. Either one of the two alternatives, fault or isoclinal folding, accounts for the apparent repetition of strata east of Shaft 1.

The conformable relation of the Boylston schist and phyllitic quartzite of the tunnel is beyond question. The same applies to the phyllite and quartzite mapped as Oakdale quartzite and Worcester phyllite in the area north of the Wachusett Reservoir through which the geologic section of the tunnel has been extended. A principal difficulty in the problem of geologic age and interpretation of structure is the isolated occurrence of the Worcester "Coal Mine" outcrop, from which the age of the Worcester phyllite formation has been deter-

mined by fossil evidence. Callaghan[1] has previously recognized the fact that the large section of less carbonaceous phyllite of the geologic section is north of the highly carbonaceous and graphitic "Coal Mine" outcrop. On the basis of having a similar lithology, with the one exception of carbonaceous material, he prefers to correlate the fossiliferous phyllite of the Worcester "Coal Mine" with the phyllite of the geologic section.

A new approach to the solution of these age problems has recently been made in the determination of the geologic age by means of chemical data obtained in analyzing certain radio-active minerals found in some of the igneous rocks intruded into the schists both in Massachusetts and Connecticut. For example, Lane[2] has recently reported the results from a micro-chemical analysis of the mineral uraninite found in the Fitchburg quarries in Fitchburg, Massachusetts. From this data he estimates the granite to be much older than late Carboniferous and probably of late Ordovician age. By using a similar method Foye[3] has found the pegmatite intruding the Bolton schist formation of Connecticut to be of Devonian age. As mapped, this Bolton schist formation is equivalent to the Amherst and the Irving schist formations of Massachusetts, the Amherst being equivalent to the Brimfield or the Brimfield-Ware formations of the tunnel.

It should be noted in the interpretations presented so far that the Fitchburg granite invasion is considered to have occurred during the latter part of the Carboniferous period. Such an age relation for this formation cannot as yet be abandoned in favor of an older age based on chemical data. The chemical determinations suggest, however, that the igneous rocks throughout the area are not all of the same age, and that the same may be true of the schist formations.

The sixth interpretation, which follows, is based on a concept radically different from any yet proposed. The viewpoints presented cannot as yet be definitely proven because they are based only on reasonable inference.

The schist rocks appear to be considerably older than the age previously assigned to them and the evidence also indicates a greater age for some of the igneous rocks.

INTERPRETATION VI — BASED ON CONCEPTION OF DIFFERENT AGES

Assumptions — Different Ages, Thrust Faulting and Igneous Invasion

Worcester phyllite	= Fossiliferous Worcester "Coal Mine" outcrop	Carboniferous Age
Oakdale quartzite	= Oakdale quartzite	
- - - - - - - -	= Unconformity	
* * * * * * *	= Igneous invasion (Fitchburg granite)	Pre-Carboniferous Age. (Late Ordovician Age?)
# # # # # # #	= Overthrust fault	
Brimfield Schist	= Phyllite (of section)	Pre-Carboniferous Age (Ordovician Age?)
Paxton Schist	= Phyllitic quartzite and quartzite (of section)	
Ware Schist	= Boylston schist	

This interpretation, illustrated in Figure 14, is an attempt to reconcile the apparent conflicting data of an older age for the Fitchburg granite and the schist formations with the structure and distribution of strata, shown in the geologic section, in proximity to rocks of Carboniferous age. The chief feature is the separation of the phyllite of the Worcester "Coal Mine" outcrop from the less carbonaceous phyllite of the tunnel section extended. The stratigraphic section east of Shaft 1 is then seen to consist of a metamorphosed quartzose sediment over and underlaid by metamorphosed argillaceous sediments. This section is similar to that represented by the Brimfield-Paxton-Ware schist series farther west. These rocks were deposited, metamorphosed, deformed, invaded by granite and eroded long before the Carboniferous period, at which time the fossiliferous Worcester phyllite and underlying quartzite were deposited.

The last three interpretations are based partly on a thrust fault relation between the schists west of the Fitchburg granite and the phyllite and quartzite strata between this granite and the composite formation mapped as "Bolton"

[1] Callaghan, E., op. cit., p. 69.
[2] Lane, A. C., Age of Fitchburg Granite, Science, Vol. 78. No. 2028, Nov. 1933.
[3] Foye, Wilbur G., Private Communication to Chas. P. Berkey, June 22, 1933.

gneiss and included schist. Emerson[1] has inferred such a relation on the Preliminary Map of Massachusetts and Rhode Island on which he has drawn a line indicating a possible fault extending from near East Woodstock, Connecticut, to South Charlton, Massachusetts. In this area the Paxton schist is mapped in contact with the Oakdale quartzite. Extension of the fault further north is not indicated but the outline of the Ayer granite mass in this vicinity suggests igneous intrusion along a weakened zone resulting from such deformation. Emerson, Keith and LaForge are in agreement as to the late Carboniferous age of the Ayer granite, which view does not conflict with the relations suggested here.

Relation of Construction to Geologic Conditions

In all underground excavation work it is expected that different rock formations will behave differently; better progress can sometimes be made in one formation than in another; one formation is apt to be less treacherous or less inclined to cave, or contains less water, or requires less timbering, or in any number of other ways behaves better than a neighboring formation. During construction of the Quabbin Aqueduct related construction and geologic data, of which the following is a summary, were gathered.

Scaling of Hard Rock

In general the quality of rock in the several geological formations was found to be highly suitable for tunneling operations, and although the rocks are of several different types they are generally of a fairly uniform quality and required very little attention after blasting, other than the usual amount of inspection. A few exceptions deserve comment, however. Excessive scaling of the tunnel arch throughout nearly the entire west heading of Shaft 4, in the Paxton schist formation, constituted a serious menace to safety and threatened to delay the progress of excavation. When the heading had been advanced to a point about 3,800 feet from the shaft, slabs of rock began to fall from the tunnel arch. The condition was most serious in the stretch of tunnel extending from 2,400 feet from the shaft to the heading. The fundamental cause of this behavior was what is known as "air slacking," a condition brought about by the action of air and moisture upon the constituents of the formation. Developing with the lapse of time, the difficulty first attracted serious attention when the easterly end of the section had been exposed to the air for about three months.

Certain peculiar mineral and structural characteristics of the rock were principally responsible for the scaling. The Paxton schist throughout this troublesome stretch is finely laminated and arranged in thin beds which have a general low dip toward the east. The rock is broken by two sets of joints, along which there has been slight movement, into large and small angular blocks and slabs. Both sets of joints were faced with a thin coating of carbonate, chiefly calcite, sometimes associated with iron sulphide minerals. Exposure to the air over a period of time caused oxidation of the sulphide minerals and softened the carbonate, thereby loosening the bond between separate blocks.

This troublesome condition was successfully overcome by the application of two and sometimes three coats of Portland cement mortar shot onto the rock surface as "gunite." Each coat was about ¼ inch thick and was applied in such a manner as to seal all cracks and joints from the air.

A section of tunnel at Shaft 2 also caused considerable concern and necessitated more watchful attention than was generally given in the routine of inspection. This section, which was excavated in the Fitchburg granite where the foliation structure is vertical or nearly so, developed excessive scaling in the arch. This scaling, however, was caused by somewhat different conditions from those responsible for scaling in the Paxton schist. Scaling of the rock in this case was due to confined strains, which, when relieved by excavation, developed horizontal fractures, allowing slabs to fall from the roof. This condition is often called "popping rock." The dangerous situation resulting from this behavior was gradually eliminated by constant attention and prying loose of slabs formed by newly developed cracks.

[1] Emerson, B. K., op. cit.

Timbering of Soft Rock

The lengths of tunnel requiring timber support and those where guniting was necessary for the correction of "air slacking" are as follows:

	Length of Tunnel Feet	Per Cent of Total Length
Permanent timber support	1,971	1.5
Temporary timber support	529	0.4
Gunite protective coating	12,046	9.3

Many intrusions of pegmatite, or coarse granite, in the Brimfield formation established conditions causing alteration and gradual decay of the adjacent micaceous schist. Narrow openings and partings along the foliation or bedding planes served as water courses so that the formation as a whole was affected, some portions becoming very soft. Throughout the worst of such sections, timber support for the tunnel roof was necessary (Plate 12). In other stretches gunite was sufficient to stabilize the rock.

Excavation was carried through several zones of crushing and close jointing without any abnormal behavior of the rock. At some points, however, such conditions were responsible for considerable overbreakage on the sides and in the arch. Timbering was constructed in some of these sections, especially where removal of loose blocks did not remedy the condition of "popping rock." In a short stretch of tunnel near Shaft 12 the rock presented considerable difficulty due to its tendency to develop pressure and move into the excavated space. This condition was due to crushing of the rock and extreme alteration of the feldspar constituents to clay.

Ground Water Circulation

Crystalline rock is normally too dense to allow much water circulation, but if such formations are heavily jointed or deeply fissured, or if they are badly broken or crushed by faulting, they may become heavy water bearers and give much trouble. It was noted during construction that water leakage was confined mainly to such structures, which in some cases were developed parallel, or nearly so, to the foliation or bedding of the rock. Small openings along the foliation of the Brimfield and Ware schists allowed a slight but continual seepage of water so that these formations always presented a moist appearance. The other formations of the tunnel area had, by comparison, a very dry aspect except in the vicinity of fractures.

The wettest single stretch in the easterly portion of the tunnel occurred between Shafts 7 and 8, in the Ware schist formation, most of the leakage being confined to the section within one mile of Shaft 8. The second largest water bearer was the Brimfield schist, the larger part of the leakage from which entered the tunnel in the vicinity of Shaft 3. Although water coming from the Brimfield and Ware schist formations was not confined to any particular type of channel there appeared to be some relation between the amount of water and the occurrence of granite intrusions. These igneous intrusions considerably altered the minerals of the schistose rock, especially adjacent to the contacts. Either rock decay has helped to develop fissures sufficient in extent to carry considerable quantities of water or the fissures were developed from deformation and encouraged both water circulation and consequent decay.

The major portion of leakage from the Paxton schist formation and the Fitchburg granite formation was confined to fissures, several of which were found to be lined with calcite crystals. At other points leakage occurred largely from joints. These channels, upon being reached by the heading, yielded considerable quantities of water over a short period and at times temporarily placed rather heavy loads on pumping facilities. After a while, however, the water was depleted and for the remaining construction period the leakage either continued at a greatly reduced rate or else stopped entirely.

The wettest section in the westerly portion of the tunnel was the stretch between Shafts 10 and 11 where excavations were carried through the Hardwick granite formation in which leakages were confined to fractures occurring as joints or as openings parallel to the foliation structure.

Hardness of Formations as Shown by Drilling Speeds

The relative hardness of the several rock formations is shown in Table 1 under the heading "Speed of Drilling." This data represents typical conditions encountered and indicates a wide range in drilling behavior. By far the softest formation was that part of the Brimfield schist occurring throughout the tunnel at Shaft 9 and in portions of the tunnel at Shafts 10 and 11. The behavior of the Brimfield formation in this respect was rather striking; throughout most of its extent the high mica content and general soft condition, due chiefly to alteration of minerals and subsequent weathering processes, was conducive to fast drilling. The portion of this formation extending throughout the east heading of Shaft 4 was considerably harder because of the great number of quartzite beds and granitic bodies.

The hardest formations, with the exception of trap rock, were the Hardwick, Fitchburg and Monson granite formations and the Oakdale quartzite. The Hardwick granite in some sections was a trifle harder than the other two granites. In general these rocks were about three times as hard to drill as the Brimfield schist. Between the extremes of hardness represented by these formations there was a rather uniform hardness represented in the several rock types of the Boylston, Paxton and Ware formations. Of these types, the more quartzose varieties of the Paxton schist, which constitute about two-thirds of the formation, were most uniform in hardness. But for the widespread intrusions of granite into the Ware schist, this formation would have been as soft as some portions of the Brimfield formation.

Methods of Tunnel Excavation

A description of the methods used in tunnel excavation[1] is included in order to supplement the data presented in Figure 15 and Table 1. This data concerns only the performance attained after permanent tunnel equipment had been installed by the contractors. The short stretches of tunnel excavated with equipment used in shaft sinking are shown on Figure 15 in solid black along the lower part of each progress chart adjacent to the shafts and are not considered in this discussion. Shaft 3 was eliminated as a construction shaft soon after construction began under the major contract for constructing the easterly half of the east portion of the tunnel and only a short stretch was excavated from Shaft 1. The contractor completed the excavation between Shafts 1 and 4 from Shaft 2.

At Shafts 2 and 4 and 9 to 12, inclusive, the full-face method of excavation was used. At the first two shafts advancement of tunnel headings was carried on continuously by drilling and mucking crews, which worked on a daily schedule of three eight-hour shifts. The work was so arranged that while blasted rock was being removed from one heading the other heading was being drilled. By this plan the contractor hoped to obtain four advances in one day and five the next. Two ten-hour shifts were employed at Shafts 9 to 12, inclusive, where the number of advances in one day was seldom under four, and at times reached five. At Shaft 12, where excavations were carried on in only one heading, three advances were often made but in order to do this the crews were required to work overtime.

The heading and bench method of excavating was used in the headings of Shafts 5 to 8, inclusive, where the work was organized on a basis of two ten-hour shifts in such a manner as to produce two rounds of excavation in each heading per day. Under this plan drilling and mucking operations were carried on together.

After using this scheme in the headings at Shaft 7 for a while the contractor adopted a modified plan in which drilling and blasting of each heading and bench was accomplished during one shift and mucking during the other. The depth of holes was increased to 10 feet, and blasting was done in two operations, the cut

[1] Several accounts concerning construction of the Quabbin Aqueduct have been published, a few of which are listed as follows:

"Construction of Wachusett-Coldbrook Tunnels," by Douglas C. Corner, U. S. Bureau of Mines.

"Boston Metropolitan Water Supply Extension," by Karl R. Kennison. Journal of the New England Water Works Association, Vol. 48, No. 2.

"Constructing a 14-Mile Tunnel for Boston's New Water Supply," Engineering News Record, Sept. 11, 1930.

TABLE 1. TABULATION OF DATA RELATING TO ROCK CHARACTER AND EXCAVATION

Rock Formation		Oakdale Quartzite	Boylston Schist	Fitchburg Granite	Brimfield Schist			Paxton Schist		Ware Schist
Method of excavation		Full face							Top Heading and Bench	
Heading in which formation occurred		Shaft 2—East		2 West	4 East*	9 West	11 West	4 West*	5 East	8 East
Average advance per shot (ft.)		7.3	7.7	7.0	6.5 & 7.3 6.1—6.9	8.8	8.3	6.8 & 7.3 6.3—7.8	6.2	6.5
Range in monthly averages—advance per shot		7.1—7.4	7.4—7.9	6.1—7.4	6.7—7.8	7.2—9.5	6.6—9.4	6.7—7.9	5.8—6.7	5.8—7.5
Number of days of zero advance and conditions responsible	Timbering	0	0	0	5	7	0	0	0	0
	Poor roof	0	0	0	2	0	0	25	1	0
	Water	0	0	0	18	0	0	0	0	32
	Holidays	0	0	2	4	5	5	4	2	2
	Repairs to plant and misc.	0	0	3	7	7	4	11	2	2
Number of daily—										
1 round shots		4	2	51	75	35	24	102	36	62
2 round shots		37	76	362	350	392	216	285	393	306
3 round shots		7	21	37	54	4	0	30	0	0
Range in number of holes in heading		30—32	31—35	30—40		38—40	29—36	32—40	TH 24—32 TH—28	TH 26—34 TH—29
Typical heading	Number of holes	31		37		38	32	37	B—6 TH—224	B—7 TH—244
	Av. lin. ft. drilled	287		345		386	346	345	B—48	B—56
Depth of holes (ft.)	Cut			9		9 & 11	10+	9	8	10
	Relief		8 and 9			9—11	10	8—9	8	8
	Trim		8 and 9			9—11	10	8—9	8	8
Speed of drilling (in./min./drill)	Range	5—9	5—12	5—9	7—15	10—20	7—20	7—11		7—14
	Typical	7	10	7	12	16	13	9		11
Average time required to drill heading (hrs.)		2—3½	Number of drills—5 1½—3½	2—3½	1½—2½	Drills—4 1½—2½	2—3	Drills—5 2—3	Drills—2 TH 5—7	
Average time required for cycle of drilling and blasting (hrs.)		4—5	3—4	4—5	3—4	2½—3½	3—4	3½—4½	9—10	
Av. lin. ft. of holes per cu. yd. of excavation		6.0	5.7	7.0	7.0	6.5	6.5	7.2	6.5	
Av. lbs. of powder per cu. yd. of excavation		5.0	4.5	6.5	6.0	3.8	4.9	6.2	6.0	

TABLE 1. (Continued) TABULATION OF DATA RELATING TO ROCK CHARACTER AND EXCAVATION

Rock Formation		Hardwick Granite		Monson Granite	
Method of excavation		Full Face			
Heading in which formation occurred		10 West*	11 East	11 West	12 East
Average advance per shot (ft.)		7.3 & 7.8	7.8	8.0	7.7
Range in monthly averages—advance per shot (ft.)		6.8—8.2 7.5—8.2	6.0—8.5	7.6—8.8	7.0—8.9
Number of days of zero progress and conditions responsible	Timbering	0	8	0	0
	Poor roof	2	0	0	0
	Water	0	4	0	0
	Holidays	5	4	0	4
	Repairs to plant and misc.	4	3	0	6
Number of daily—					
1 round shots		61	38	17	23
2 round shots		497	372	252	300
3 round shots		0	0	0	78
Range in number of holes in heading		36—44	31—36	29—36	30—42
Typical heading	Number of holes	40	32	36	
	Av. lin. ft. drilled	440	288	396	
Depth of holes (ft.)	Cut	9 & 11	9+	9+ & 11+	
	Relief	9—11	9	9 & 11	
	Trim	9—11	9	9 & 11	
Speed of drilling (in./min./drill)	Range	5—12		5—9	
	Typical	6		7	
Average time required to drill heading (hrs.)		3—4	Number of drills—4	2½—3½	
Average time required for cycle of drilling and blasting (hrs.)		4—5		3½—4½	
Av. lin. ft. of holes per cu. yd. of excavation		7.0	6.7	6.5	7.3
Av. lbs. of powder per cu. yd. of excavation		5.7	6.0	5.3	5.1

*In these headings an improvement in the progress of tunnel excavation resulted from changes in the organization. Figures relating to the advance per shot indicate the extent of improvements, so far as the individual rounds or advances were concerned. Additional improvement was made in the sequence of operation so that there were fewer one round days, and more two round days.

Note: TH = Top Heading
B = Bench

and bench holes being loaded and shot first. If, upon examination, the rock was found to have been broken to the full depth required the remaining holes in the heading were loaded and fired. If, as sometimes happened, the rock was not broken to the full depth of the cut holes, additional powder was placed in the bottom of these holes and detonated with the rest of the heading.

Drilling. Drilling of the headings, where the full-face method of excavation was used, was accomplished from drill carriages designed and constructed by the contractors. These carriages were provided with all equipment necessary for drilling the full number of holes. The carriages finally adopted at Shafts 9 to 12 were an improved type of those formerly used, in that the drilling bars, mounting two upper and two lower drilling machines, were an integral part of the carriages. Previous to this installation, and at Shafts 2 and 4, drilling was done by five drills mounted on two horizontal bars, one upper and one lower, which were blocked and wedged to the tunnel side walls. The outline of the headings and the location of drill holes are shown in Figures 16 and 17.

Drilling of top headings was accomplished by two drilling machines mounted on short horizontal arms clamped to two vertical drilling columns, which were blocked and wedged to the tunnel roof and the bench. Bench holes were drilled by mounting the machines used in drilling the headings on a horizontal bar which was located in front of the bench face and wedged to the tunnel sidewalls. A typical drilling diagram showing the location of holes in the top heading and bench is shown in Figure 17.

Mucking. At Shafts 2 and 4 and 9 to 11, inclusive, blasted rock was loaded into steel cars of about 3 cubic yards capacity by means of electric power shovels. At Shaft 12 the contractor installed a drag-line excavator of his own design and manufacture. This machine was equipped with a conveyor belt of sufficient length to allow a full train of five cars, each of 3 cubic yards capacity, to be loaded without the necessity of switching or bypassing cars. With the power shovels it was necessary to move empty cars from the front to the rear end of the train, where the loader could reach them. At Shafts 5 to 8, inclusive, where the top heading and bench method of excavation was adopted, mucking was accomplished by means of mechanical shovels of the air driven type. Hand mucking was used for a short while at Shaft 5 and for a longer period at Shaft 6. Animal power was employed for hauling trains of three cars each of about 1⅔ cubic yards capacity from the heading to the shaft. In headings where the full-face method of excavation was used hauling was done by storage battery locomotives.

Throughout the easterly portion of the tunnel loaded muck cars were hoisted out of the tunnel by means of balanced cages or elevators. Upon reaching the shaft platforms at the surface the cars were run off the cages, made up into trains and hauled to the place of dumping on the spoil pile. Various kinds of motive power, including electric and gasoline locomotives and animals, were used for hauling to the spoil areas. At the shafts in the west portion of the tunnel excavated rock material was dumped into skips similar to those used at some mines. Upon reaching the top of the shaft the skip was automatically dumped and the wasted rock material discharged into cars and transported to the spoil pile. At Shaft 12, due to special requirements, the contractor used motor trucks for distributing excavated material over a large area.

The average time required for drilling and shooting a round in the several headings is shown in Table 1. The average time for mucking at Shafts 2, 4, 9 and 10 was from 2½ to 3½ hours, at Shafts 11 and 12, from 3 to 5 hours, and at Shafts 5 to 8, inclusive, where the top heading and bench method was used, from 5½ to 6½ hours.

Rock Breakage. Separation of the rock formations into blocks by the occurrence of joints or "slips" affected construction operations very little, although in several places high and wide overbreakages were caused by closely spaced joints or by the presence of many intersecting smaller fractures, which had been caused by crushing or other deformation movements within the formations.

In the general vicinity of the Quabbin Aqueduct are large supplies of natural sand and gravel suitable for use as concrete aggregates. These supplies are found particularly in the morainal and kame type of deposits located within the larger valleys, in which modified glacial drift is deposited as shown in Figure 2.

The specifications for tunnel construction permitted the use of suitable materials from the shaft and tunnel excavations for concrete aggregates. The rock, with the exception of the soft portions of the Brimfield schist formation extending between Shafts 9 and 10, and in two short stretches adjacent to Shafts 3 and 11, was found to be suitable for this purpose.

Rock crushing and concreting plants were erected at Shafts 2, 4, 7, and 9 to 12, inclusive. Most of the tunnel spoil crushed at these plants was composed of schistose rocks which had been rendered harder and more massive by the large proportion of intruded igneous material. Approximately one third of the spoil material was obtained from granite formations which were considered suitable for aggregate material. The mineral content of the various types of schist and granite, with but one exception, was such as to cause little concern about the resistance of the crushed material to further alteration or decay when incorporated in concrete. Portions of the soft micaceous Brimfield schist excavated from the headings at Shaft 9 disintegrated rapidly in the spoil pile to a sandy and flaky rock material. Only the rock from intruded igneous bodies appeared free from this unstable condition. Consequently, much of the aggregate used in concrete at Shaft 9 was obtained from a nearby sand and gravel deposit and from more suitable material at Shaft 10.

Geology of Main Dam and Beaver Brook Dike

The preliminary investigations indicated that a large reservoir could be created in the Swift River Valley. This reservoir would require construction of a dam on the main river about three miles below the village of Enfield, supplemented by a dike across the valley of Beaver Brook about three miles northeast of the dam on the divide between the Swift and Ware rivers.

The Swift River is one of the principal tributaries of the Chicopee River and drains an area of about 213 square miles above its confluence with the Ware River at Palmer. It is made up of three branches, two of which, the East and Middle Branches, unite in the southwesterly part of the town of Greenwich, about two miles above the village of Enfield, while a third, known as the West Branch, joins the main river about a mile and a half below that village. The watershed of the Swift River is characterized by a series of high ridges running generally parallel in a north and south direction. The middle and upper portions of the valley are occupied by an extensive sandy plain, above the level of which a number of rocky hills rise from 300 to 500 feet. The Middle Branch of the river flows in a southerly direction through this plain from its headwaters in New Salem and North Dana. The East Branch, which drains a high and hilly country in the easterly part of the watershed, enters the plain near its southerly end, joining the Middle Branch near the southwesterly corner of the town of Greenwich. The main river turns abruptly to the southwest not far below this point and enters the comparatively narrow valley in which the town of Enfield is situated. The sand plain, however, extends farther south rising gradually to the broad, low divide between the Swift and Ware River watersheds. This topographic condition makes construction of a dike necessary if the water impounded at the main dam is to be retained in the reservoir. Below the point of confluence of the East and Middle Branches the main river continues through the valley, in which the villages of Smiths and Enfield are located, to its junction with the West Branch, where it turns south and flows through the wider valley below.

Conditions at the low point of the divide between the Swift and Ware rivers northeast of the main dam were found to be unfavorable for the economical construction of a dam or dike at that point, but a favorable site was located in the valley of Beaver Brook about a mile south of the divide, where advantage could be taken of the shorter distance between the side ridges.

The sites chosen were investigated by a large number of borings[1] which provided information regarding the depth to and nature of the rock formations, the number and size of boulders and the quality of the overburden.

The flow line of Quabbin Reservoir will be at an elevation 530 feet above Boston City Base. The reservoir will have a capacity of about 415 billion gallons (1,270,000 acre-feet) and will have a water surface area of about 39 square miles. The flow line will be about 118 miles in length, exclusive of the shore line of the islands. The average depth of water will be about 50 feet. The westerly arm of the reservoir will extend for twelve miles north of the main dam in the valley of the West Branch, and the easterly arm for sixteen miles above the dike in the broad valley of the East and Middle Branches. The drainage area above the dam and dike is 186 square miles. In addition to the Swift River run-off the reservoir may store waters diverted at Coldbrook from a drainage area of 97 square miles of the Ware River, and possible diversions at Shaft 2 from a drainage area of 43 square miles of the Quinapoxet River.

Origin of the Swift River Valley

The Swift River system is a development, during pre-historic times, from three independent but more or less parallel drainage courses; the pre-Glacial or Tertiary "Muddy," "Beaver" and "Swift" rivers. These are indicated on Figure 2. The Tertiary "Muddy" River has already been discussed on page 9 of this report.

The Tertiary "Beaver" River drained approximately the same territory as the present Middle and East Branches of the Swift River. South of Mt. Pomeroy, its several branches formed a single stream which flowed south through Beaver Brook Valley, crossed the Ware Valley, and continued southward through Palmer, and entered the well-defined Monson Valley southeast of Palmer.

The Tertiary Swift River flowed through the valleys of the Swift River West Branch and the Swift River southward to the Ware-Chicopee Valley, whence during a part of the time it may have continued by way of the Quaboag Valley into the Monson Valley.

The rock floors of the Muddy, Beaver and Swift River valleys, in the order named, are successively lower in elevation. At the lowest point in Muddy Brook Valley on the tunnel line the rock floor is about 480 feet above sea level; in Beaver Brook Valley at the dike site the floor is at about Elevation 290; at the main dam the lowest point is at about Elevation 267.

The lower floor of Beaver Brook Valley indicates stream erosion over a considerably longer period than in Muddy Brook Valley and leads to the conclusion that the pre-Glacial "Muddy" River was cut off by the "Beaver" River system during the earlier part of the Tertiary period. There is no evidence to indicate that the difference in elevation of the rock floors is due to materially greater glacial erosion in Beaver Brook Valley than in Muddy Brook Valley, and, although glacial erosion had a prominent part in their formation, stream erosion was a more important factor in first eroding and fixing the general trend of these valleys.

The final stage in the development of the Swift River was completed when the "Beaver" River was cut off and captured by the Tertiary Swift River West Branch through dissection of the divide between the two.

The broad valley of the Middle and East Branches north of the dike is an interesting and peculiar topographic feature for which certain geologic conditions were partly responsible. The outline of the valley conforms to the boundaries of the Monson granodiorite formation which is flanked by schist strata outcropping in the side ridges. The narrow portion of the valley in which the dike is located is also the section where the flanking schist rocks are closest. The topographic expression of the valley and the distribution of the rock formations is not merely a coincidence, for it seems the first is dependent upon the latter. Before the Glacial period the rocks were extensively weathered and decayed. This is particularly true of the granodiorite formation where weathering was greatly accelerated by reason of the steep foliation or bedding structure,

[1] Hammond, N. LeRoy, Diamond Drill Borings for the Swift River Dams, Journal of the Boston Society of Civil Engineers, January, 1929.

the coarse grain, the great abundance of feldspathic constituents, and the fact that it is broken up by several sets of joints, a prominent one of which is nearly horizontal or at right angles to the foliation. The schist rocks are of finer grain, contain much less feldspar, and fewer joints, and consequently were more resistant to weathering and decay. As the glacier advanced southward in the valley the thick mantle of decayed rock was removed by abrasion, permitting the ice to penetrate into the many cracks and other weaknesses of the rock and wedging blocks of rock further apart. These blocks were eventually dislodged by, and carried along in, the glacial ice. The two principal weaknesses of the granodiorite, the steep foliation and the horizontal set of joints, aided this type of erosion or glacial plucking. The schist rocks were better able to resist this kind of erosion, chiefly because of fewer joints in the directions more apt to facilitate plucking action.

Detailed Investigations at Main Dam and Beaver Brook Dike

Borings at the sites of the main dam and the dike penetrated bedrock to depths of at least 15 feet and samples of the overburden were taken at 5-foot intervals and in some cases more often. These explorations revealed wide, smooth valleys and showed that the underlying rock was of good quality and substantial. Its crystalline character was found to be such that no special construction difficulties were anticipated. The overburden was found to be thick and porous, substantial enough to support the contemplated structures but not sufficiently impervious to hold back the reservoir water. The porosity of the overburden, together with its great thickness, necessitated a type of construction that would not permit leakage under the structures.

Four concrete exploratory caissons, one at the dike and three at the dam, were constructed in order to permit more thorough investigation of the qualities of the overburden, the feasibility and cost of open and pneumatic caissons for cut-off walls and the possibility of lowering the ground water by pumping. As the sinking of the caissons progressed to bedrock the drift material was sampled continuously for purposes of studying its characteristics. From information obtained by sinking these caissons and the subsequent pumping from them, it was shown that the ground water, which, at the dam site, was approximately at river level, about 120 feet above the low point of ledge, and at the dike, at brook level, about 130 feet above the low point of ledge, could be satisfactorily lowered so that the larger portions of the concrete core wall at each site could be built in the dry or with very low air pressure and that caisson construction for use as a cut-off wall was feasible for both sites, providing an economical and satisfactory cut-off. Such core walls, constructed by sinking and afterwards joining a series of similar caissons, have been constructed at Beaver Brook dike and at the main dam.

Detailed investigations of the natural materials adjacent to the sites were made for purposes of studying their use and behavior in the dam and dike. Samples were carefully gathered and tested in the Soil Testing Laboratory. The depth of deposits was determined by borings and detailed observations were made in test pits and large shovel cuts. In this way deposits were exposed on a large scale and a better understanding of the range in variety of the materials obtained.

Glacial Deposits of Beaver Brook and Swift River Valleys

The deposits within the Beaver Brook and Swift River valleys consist chiefly of modified glacial drift. These are assorted and stratified sand and gravel with bouldery accumulations. Within these two valleys a relation exists between the topographic expression of the surface forms and the distribution and character of the modified and unmodified deposits. In general, the unmodified drift of the ground moraine which occurs in the higher areas was deposited directly by the ice with very little if any assorting action by water and as a result the ground surface throughout these areas is quite regular and the underlying rock topography conforms roughly to the surface topography. In contrast, the irregular surface topography formed by gravel and sand knolls and ridges, due to the irregular deposition of materials by glacial streams flowing in channels under the ice or along the front and sides of the ice, is typical of the

areas in which the modified drift occurs. Parts of the modified drift, especially in the Swift River Valley, consist of terrace-like deposits which often occur on both sides of the valley at approximately the same elevations. These terraces represent deposition between an ice lobe of the receding glacier and the valley side hill, or in some cases, the remnants of a blanket deposit which was originally spread over the surface of the valley glacier. As the ice melted, portions of the deposits slumped and were carried away, leaving those on the sides more or less undisturbed. These deposits now appear as terraces having flat or gently sloping surfaces.

The great variation in quality and texture presented by the modified drift, as well as variations in the structural relations and extent of individual layers, lenses, and beds, is a direct result of the way in which they were deposited. Layers of sand or gravel pinch out and change in quality along their lateral extent. They are overlapped by other layers which differ from them sufficiently to form a succession of beds, the whole assemblage forming a variably assorted deposit.

Materials for Construction

Areas upstream and downstream from the dike site within a reasonable hauling distance and which surface conditions indicated might be expected to yield suitable materials for earth dam construction, were investigated to determine quantities of overburden available above the ledge, and samples from test pits and bore holes were taken for mechanical analysis and other tests for suitability. The materials in each of the probably usable areas were then further investigated by excavating a shovel cut to a face 25 or 30 feet high. The topsoils available within a reasonable distance were also sampled and tested.

In the upland areas northeast and northwest of the dike topsoils were found to be available in sufficient quantity to provide impervious material for refilling the open trench excavation adjacent to the concrete core wall and for preparing the foundations for the hydraulic core of the embankment above.

Explorations of possible borrow areas for materials for the main dam were made both upstream and downstream from the site in similar manner to that employed at the dike. Sufficient quantities of suitable materials were found to be available for hydraulic construction and there is a sufficiency of topsoils upstream from the site to furnish impervious filling as required.

The embankment for the main dam will contain about 4,000,000 cubic yards and that for the dike will require about 2,500,000 cubic yards. The top of the embankment at both dam and dike will be at Elevation 550, 20 feet above the normal full level of the reservoir.

Cross Section of Valley at Main Dam and Beaver Brook Dike

The data used in preparing the two cross sections, Figures 18 and 19, concerning the glacial overburden at the dam and dike, was obtained by actual observation and measurements during construction of the caisson cut-off walls. The sections show the actual number and distribution of large boulders having volumes in excess of one-half cubic yard.

The terms used in the legend to describe the gravels, which were found to be extremely variable in texture, refer to the average composition of the sand portions, which often consisted of layers and small beds of fine sand and rock flour. The materials classed as coarse and medium sand, fine sand and clay, rock flour and silt, especially the latter two classes, show considerable uniformity in texture throughout their extent. It will be noted that a large part of the overburden in each valley is the material designated as gravel containing coarse and medium sand.

The sand and gravel beds certainly were not all deposited under similar conditions, although they were all laid down during the final stages of glacial recession when the valleys were being freed of ice. Some of these deposits were formed while the glacier still remained in the valleys, others, when there was little, if any, glacial ice left.

The beds of fine sand, clay, rock flour and silt were deposited in shallow ponds and lakes formed behind temporary dams composed of glacial drift and ice. The coarser sand and gravel materials were deposited upstream, but the finer

sediments were carried downstream in suspension, finally settling out to form fine sand and clay beds which are often laminated. These deposits do not necessarily represent a single stage of release from glacial ice followed by deposition, for they could have been, and frequently were, deposited, eroded, and redeposited before being laid down in their present formations.

Several beds of rock flour, which occur at intervals throughout the vertical extent of a thick deposit of fine sand, are shown in the cross section of the dike, Figure 18. These are essentially the same as lake deposits and indicate repetition of conditions which favored the formation of clay or rock flour bands.

The abrupt change on the east side of the valley from deposits of uniform texture to those showing great textural variability is due chiefly to the finer grained sediments having been deposited against a wall of ice and drift which occupied the middle portion of the valley. The beds of fine-grained material on the west side and in the upper middle portion of the valley apparently were deposited in depressions formed by ice blocks. Similar clay and rock flour deposits of limited size occur as small bodies or lenses in larger deposits of coarser sand at scattered points throughout the valley.

The cross section of the dam shows only a few minor deposits of extremely fine grained material. Rock flour, clay and silt were encountered here at many points but these occurred in small lenses and thin beds and in only a few instances in sufficient magnitude to allow estimating their continuity. A large part of the overburden, however, is capped by a rather thick deposit of uniform fine sand varying somewhat in texture, and occurring in thin beds or streaks of rock flour or clay and somewhat larger beds of coarser sand. This deposit was formed in a temporary lake or pond or was laid down under conditions where the carrying capacity of the glacial streams was greatly reduced. Similar sand strata occur for several miles north in the valley and form the extensive flat areas so much in evidence.

The origin and the method of deposition of the boulders in the coarser gravel deposits, all of which are too large to have been transported by glacial rivers, are particularly interesting. As the glacier advanced over the country large blocks of rock were picked up and became firmly lodged in the lower part of the glacier and were carried along by it. When changing climatic conditions halted the advance of the glacier and recession of the ice began, large quantities of sand, stones and boulders were dislodged. This melting process took place not only on the exposed upper surface of the glacier but also along the under side. Parts of the sub-glacial accumulations thus formed were carried along by sub-glacial streams and eventually deposited, but the larger boulders, upon being dislodged, remained in much the same position that they assumed when dropped by the ice, accounting for the distribution and concentration of boulders in the lower portions of the valley overburden.

The concentration and size of boulders at the dike site was greater than at the dam site, thus substantiating to some extent the explanation of the broad Swift River Valley in Greenwich and New Salem. The increased width of the valley in this section has been ascribed to lateral erosion by glacial scour after the main trend of the valley had been fixed by pre-Glacial stream erosion. As there is no difference in rock character between the boulders and the Monson granodiorite the evidence points toward the conclusion that practically all of the boulders at the dike were plucked from the Monson granodiorite formation.

Rock Formations of the Valley Floor

The rock formations at the dam and dike are different both in character and origin. The simplest rock type occurs at the dike and may be briefly described as a foliated gray granite but technically it is a variety of granite and is known locally as the Monson granodiorite, which has been described in this report as an important tunnel formation between Shafts 11 and 12.

The rock at the dam showed considerable variety in character and behavior. C nsidered as a whole it might be classed as an injection schist or gneiss and in m ny ways is similar to the schist formations along the tunnel. There are three prncipal rock types represented as follows:

1. Micaceous schist, which is similar to the Brimfield and Ware schist ormations.

2. Sandy or quartzose schist, which is similar to the Paxton schist formation.
3. Igneous rock, granite and pegmatite.

The schistose varieties are largely interbedded and have been strongly deformed into small sharp folds. The great variation in these rocks is further emphasized by the abundance of igneous intrusions in the form of small dikes, veins, bands and lenses. These intrusions more often occur as granite or pegmatite bodies which are oriented parallel to the foliation structure of the schist. Veins and dikes also occur which transect the schist strata. All stages of granitization of the schists may be seen, which is a direct result of intense soaking by granitic constituents. On the Geologic Map of Massachusetts and Rhode Island the two varieties of schist are mapped as separate formations, the Erving schist and the Amherst schist. The evidence which would warrant such a classification was not found in the section exposed at the dam. The interbedded relations of micaceous and sandy schist was observed frequently in the Brimfield and Ware formations of the tunnel, and in the Paxton formation, especially near the contacts of the middle member. It is certain that these rocks at the dam are related to one of these formations, but to which one it is difficult to say.

As the caissons for the dam and dike core walls reached the underlying rock floor the rock surface was cleaned and such rock as was not thoroughly a part of the ledge formation was removed. Much of this consisted of broken and detached blocks caused by jointing and by cracks along the foliation structure. A comparison of the two cross sections shows the relative amount of this kind of excavation and also indicates the condition and relative soundness of the original rock floor at the time it was exposed. The Monson granodiorite at the dike was found to be of a very substantial quality, only a small amount of rock excavation being necessary. The original surface in general was found to be hard and few instances of extensive rock decay were noted. The rock floor exposed by the caissons is an eroded surface protected originally by a rock cover, which was removed later by glacial abrasion and plucking. Weathering has attacked the rock very little since glacial times.

The quality of the rock at the dam was inferior to that at the dike, the micaceous schist strata being badly weathered and decayed in places, and considerably more excavation was required in order to reach sound rock. This condition, by reason of the steep foliation and interbedded character of the rocks, extended to considerable depths. The granitic portions and quartzose schists, in contrast, were sound, but considerable volumes of this better quality of rock were removed in order to remove the soft micaceous rocks. The beds of the different schist strata cut across the axis of the dam nearly at right angles, which made it all the more important to reach sound bedrock.

At least some of the decayed rock is judged to antedate the glacier. The two rock spurs, which cause the valley to become narrower and which form the dam abutments, acted as buffers in minimizing the amount of glacial abrasion. Also the effect of plucking was less here than at the dike because of fewer horizontal joints, which, however, were present in small numbers and necessitated the removal of the resulting disjointed blocks.

Geological Studies Related to Highways

Highway Locations

The Quabbin Reservoir will necessitate the abandonment of many miles of roads in substitution for which about 26 miles of new highway have already been constructed, about 5 miles being between the present Ware-Enfield road and Belchertown, and the remaining 21 miles a continuous stretch along the west side of the reservoir from Belchertown to within 4 miles of Orange, known as the Daniel Shays Highway.

Foundation and Pavement Materials

A geological survey of the country through which the new highways extend was made, the object of which was to locate sand and gravel deposits suitable for road foundations and to determine the suitability of some of the rock formations for use as road material.

Extensive deposits of modified drift, sand and gravel were known to occur in

the valley of the Swift River West Branch. Except for a short stretch where the highway crosses this valley these deposits are located from 2½ to 5 miles hauling distance, over steep grades, from the new road. Borrowing foundation material from this area would be expensive and a special effort was made in surveying the higher ground to locate sand and gravel deposits, a few of which were found which had collectively sufficient volumes of material suitable for the foundations. The deposits appear to be confined to rock depressions and small valleys which are tributaries of the Swift Valley. During the retreat of the glacier the outlets of these depressions became clogged, in much the same manner as the larger valleys, causing sand and gravel materials to be deposited.

The physical properties of toughness and hardness required in crushed stone for road metal are such that only rocks of igneous origin are suitable. A particular type of igneous rock known as diabase or trap rock fulfills the requirements most satisfactorily and in practice has become the standard material for macadam roads. Occasionally, however, other types of igneous rocks are found which are also suitable for the wearing or top course of pavements.

The rocks along the highway and throughout the adjacent country are of a crystalline character and mostly of igneous origin. The several varieties known to be available included igneous granite and diorite and an igneous quartzose rock. The quantity of crushed stone required was about 117,000 tons and it was believed that if this quantity of stone could be quarried from some local rock formation the savings might be quite appreciable. Otherwise the road metal would have to be obtained from commercial trap rock quarries.

The country adjacent to the highway was carefully surveyed and a few large ledges of igneous rock were found which showed promise as potential quarry sites. The several sites examined eventually were reduced to four, two of which were located in a dioritic formation, one in a quartzose rock formation, and the other on a newly discovered diabase or trap rock dike. The trap dike is located about three miles north of Pelham, a short distance over the town line in Shutesbury. It cuts across the highway at this point, varies from 75 to 100 feet or more in width and extends cross-country for several miles in a northeasterly direction. It is shown on the geologic map, Figure 10.

Tests of samples from the four prospective quarry sites proved two to be suitable for the surface course of the pavement; one very nearly passed the test, and the other failed. The rocks submitted for physical tests represent a rather wide range in character and their relative value as road material is shown as follows:

Rock Character	Location	French Coefficient of Wear	Toughness	Remarks
Diabase (trap rock)	Shutesbury	21	33	Suitable for both top and bottom courses.
Massive diorite	Packard Mt. New Salem	15	10	Suitable for bottom course. Average rock probably more suitable than indicated.
Igneous quartzose rock (Slightly foliated)	Pelham	17	15	Tested rather favorably but its average quality is more adapted to secondary road construction.
Foliated, banded diorite	Orange-New Salem	12	5	Poor quality and unsatisfactory.

The information relative to the location and character of the materials available for road materials was furnished to prospective contractors and the contracts provided that the trap rock dike which was located on land owned by the Commission might be used by contractors for road construction. The successful bidders purchased stone from commercial trap rock quarries at prices which were undoubtedly much lower than would have been the case had the presence of this trap rock deposit not been discovered, resulting in substantially lower prices to the Commonwealth.

Summary

Construction of the Quabbin Aqueduct and Reservoir has contributed toward a better understanding of the geology of central Massachusetts. Some of these contributions consist of the presentation of new geologic data, whereas others merely emphasize the difficulties involved in reaching a full understanding of the geological history of this part of the state. Certain portions of the material

presented concern the more practical or applied aspects of the geology as related to the several structures. The points of particular interest regarding these two phases, which have been elaborated in the text, may be summarized as follows:

1. Geologic formations have been restudied and in a few cases redefined. The Paxton schist formation was found to be composed of two similar members separated by a third dissimilar member and not of a single unit as previously described and mapped. The Brimfield type of schist was found to occur both above and below the Paxton series, which made it necessary to designate one of these occurrences by the new formational name of Ware schist.

2. A geologic section showing the distribution of formations and the geologic structure over a belt 30 miles wide is included. All but five miles of this section was studied in the tunnel where fresh exposures were available and where the geology could be mapped in greatest detail.

3. The question of relative geologic ages of the schist formations on the one hand and the recognized Carboniferous rocks on the other is still unanswered despite the excellent opportunity to view the schist formations in the tunnel. This uncertainty is due to the large mass of Fitchburg granite separating the formations into two belts and destroying much of the required evidence. Several alternative structure sections drawn through this critical area have been submitted. These do not contribute a positive solution to the age problem but they do serve the purpose of emphasizing the conflicting evidence both structural and chemical. As stated previously, the schist formations are believed to be older than the Carboniferous rocks and may be of Ordovician age or even older.

4. The Fitchburg granite was found to contain large masses of schist in all stages of granitization. These masses, remnants of an older rock series, show a strong foliation structure which is distinguishable even in the portions represented by intrusive granite. A large part of the granite has been formed by injection and replacement of the Brimfield schist. The foliation structure of the granite has been inherited from that of the older schist rocks. Such an explanation of origin is also applicable to portions of the Monson and Hardwick granite formations.

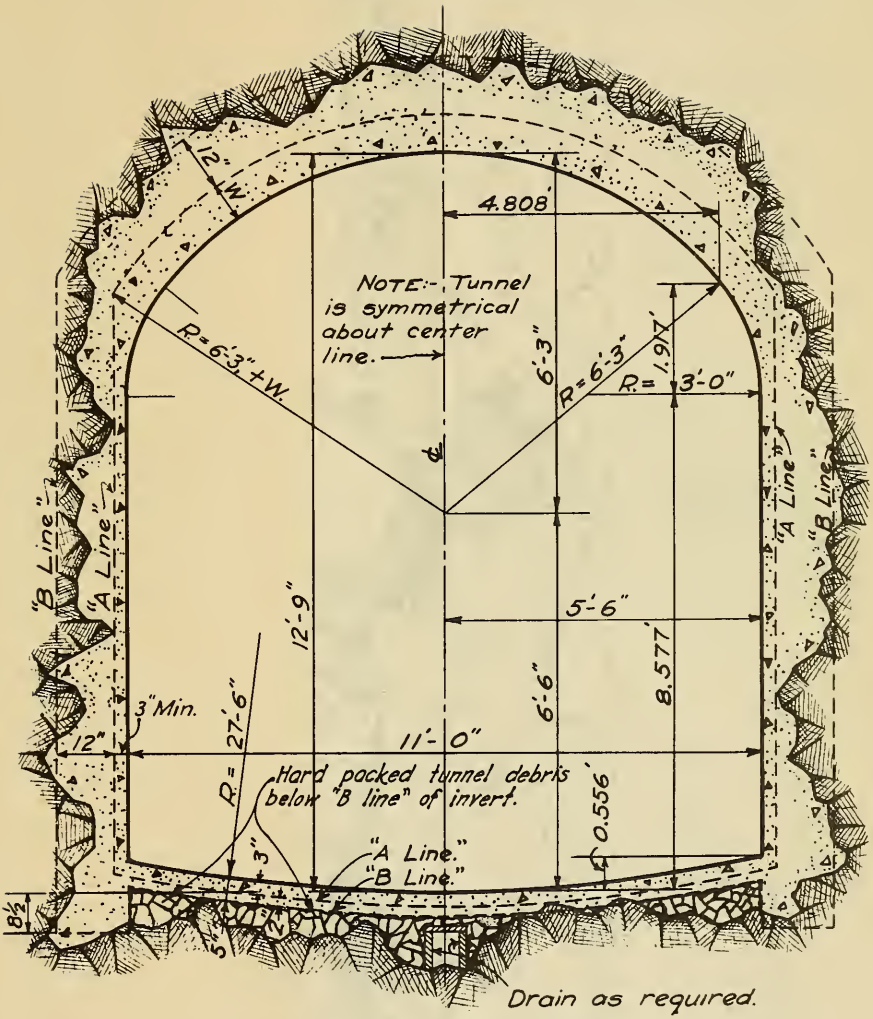
5. Sixty drawings showing the detailed geology of much of the tunnel are appended to this report. These, together with the hundreds of rock samples housed in the Ware River intake building at Shaft 8 near Coldbrook, constitute a unique record of actual geological conditions.

6. The most important pre-Glacial or Tertiary rivers have been traced and rock profiles based on borings have been drawn. These profiles indicate the depth to which some of the Tertiary valleys were eroded before they were filled with glacial materials.

7. Construction of the cut-off structures of the main dam and Beaver Brook dike has made it possible to present generalized cross sections of the valleys in which these are located. The detail presented in these sections, especially that related to boulders, indicates the character and quality of the glacial overburden more accurately than would have been possible by interpretation of borings alone.

8. The tables and charts concerning construction are submitted as a record of the performance attained in construction of the tunnel which is further correlated with the several rock formations.

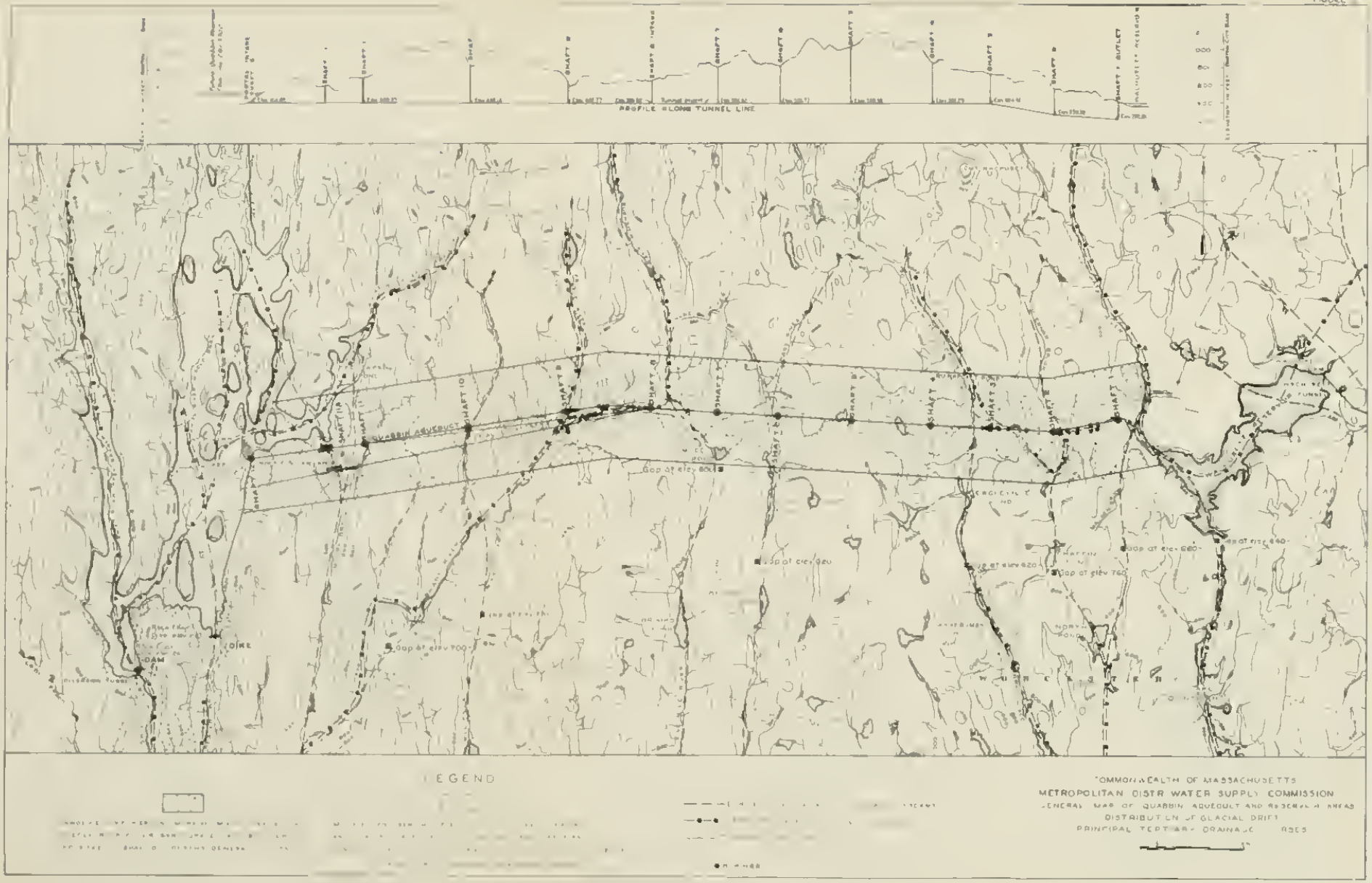
FIGURE 1



TYPICAL TUNNEL SECTION

2 1 0 2 4 FT.

FIGURE


PROFILE ALONG TUNNEL LINE
SHAFT 10
QUABBIN AQUEDUCT
DAM
LEGEND
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN DISTR WATER SUPPLY COMMISSION
GENERAL MAP OF QUABBIN AQUEDUCT AND RESERVOIR AREAS
DISTRIBUTION OF GLACIAL DRIFT
PRINCIPAL TERTIARY DRAINAGE

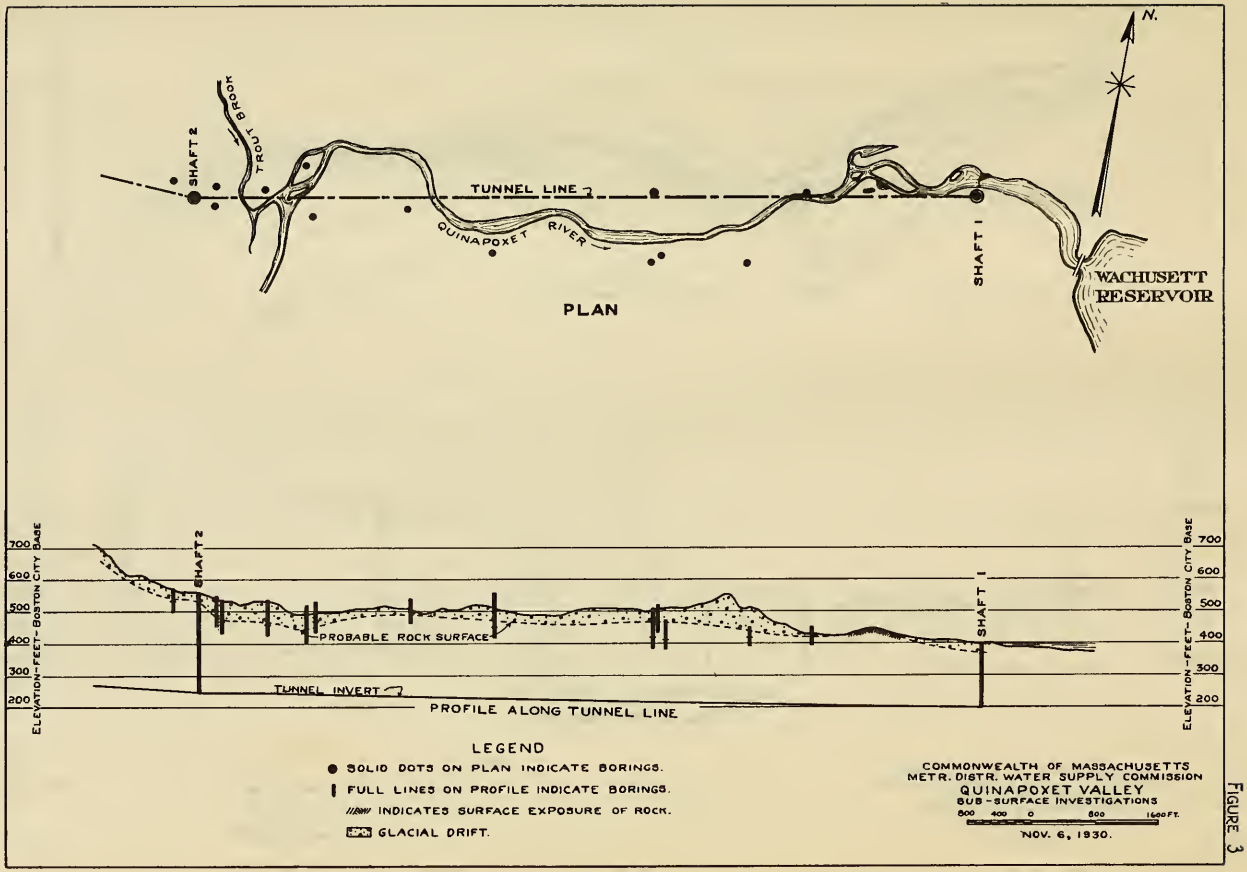

N.
SHAFT 2
TROUT BROOK
TUNNEL LINE
QUINAPOXET RIVER
SHAFT 1
WACHUSETT RESERVOIR
PLAN
ELEVATION-FEET-BOSTON CITY BASE
700
600
500
400
300
200
SHAFT 2
PROBABLE ROCK SURFACE
TUNNEL INVERT
SHAFT 1
PROFILE ALONG TUNNEL LINE
LEGEND
SOLID DOTS ON PLAN INDICATE BORINGS.
FULL LINES ON PROFILE INDICATE BORINGS.
INDICATES SURFACE EXPOSURE OF ROCK.
GLACIAL DRIFT.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUINAPOXET VALLEY
SUB-SURFACE INVESTIGATIONS
800 400 0 800 1600 FT.
NOV. 6, 1930.

FIGURE 3

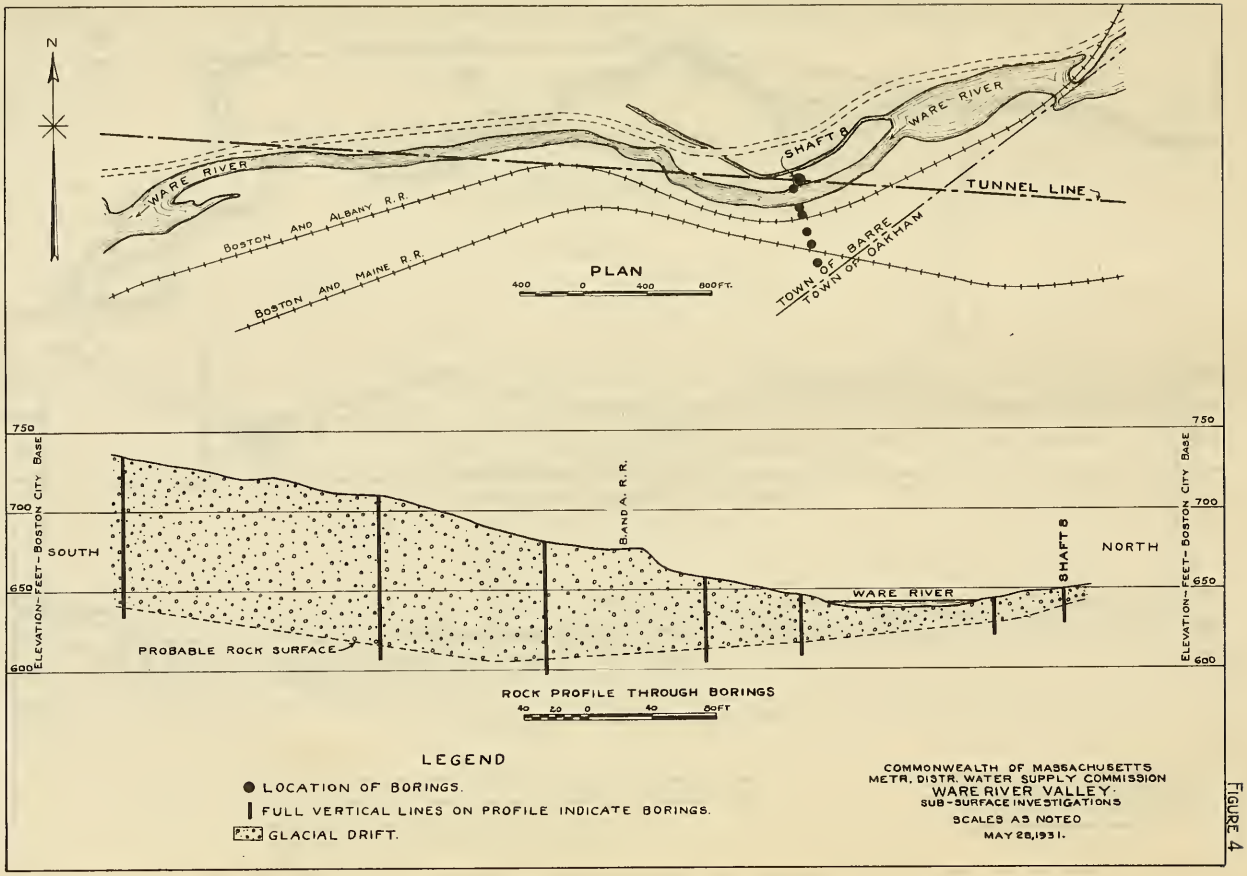

N
WARE RIVER
BOSTON AND ALBANY R.R.
BOSTON AND MAINE R.R.
SHAFT B
WARE RIVER
TUNNEL LINE
TOWN OF BARRE
TOWN OF DARTHAM
PLAN
400 0 400 800 FT.
750
700
650
600
ELEVATION—FEET—BOSTON CITY BASE
SOUTH
B. AND A. R.R.
SHAFT B
NORTH
WARE RIVER
PROBABLE ROCK SURFACE
ROCK PROFILE THROUGH BORINGS
40 20 0 40 80 FT
LEGEND
LOCATION OF BORINGS.
FULL VERTICAL LINES ON PROFILE INDICATE BORINGS.
GLACIAL DRIFT.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
WARE RIVER VALLEY
SUB-SURFACE INVESTIGATIONS
SCALES AS NOTED
MAY 28, 1931.

FIGURE 4

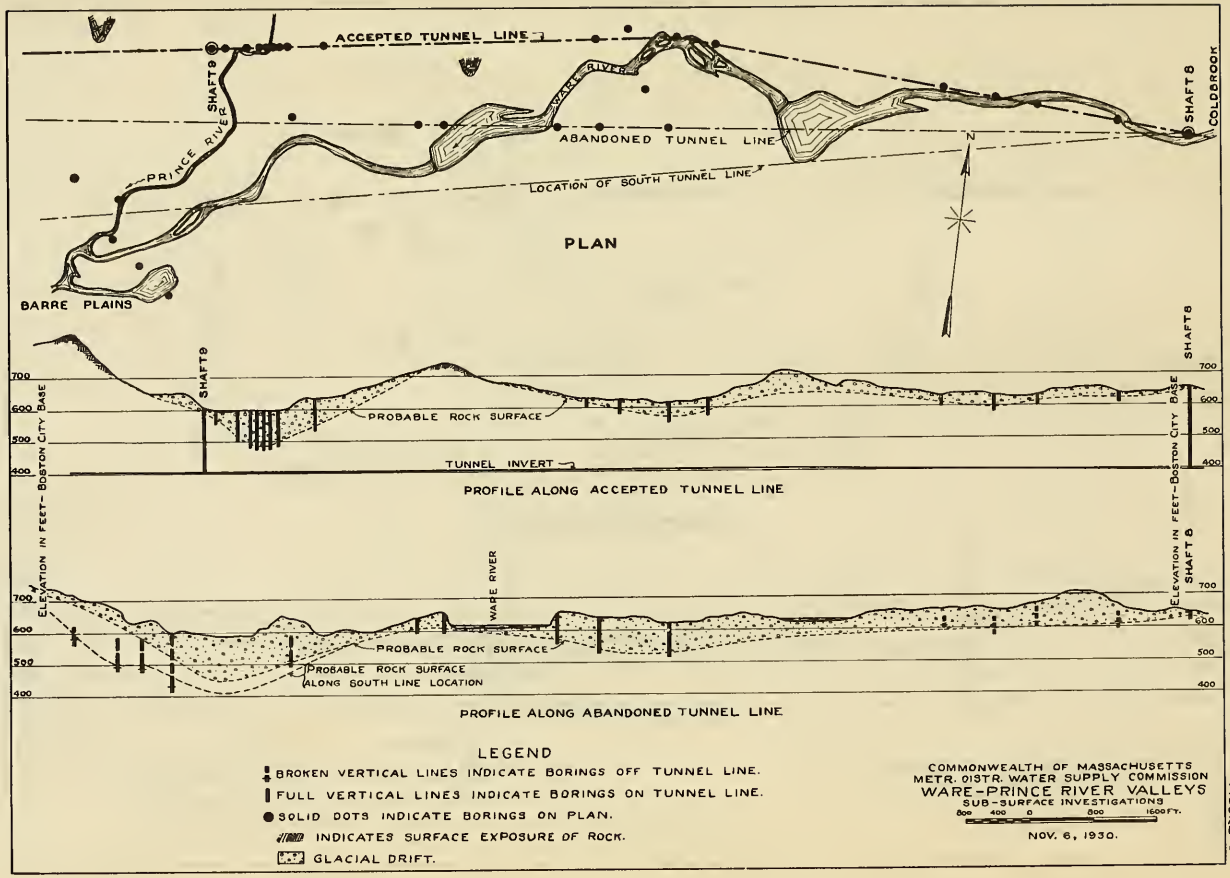

ACCEPTED TUNNEL LINE
SHAFT 8
PRINCE RIVER
WARE RIVER
ABANDONED TUNNEL LINE
LOCATION OF SOUTH TUNNEL LINE
SHAFT 8
COLDBROOK
N
PLAN
BARRE PLAINS
SHAFT 8
SHAFT 8
700
600
500
400
ELEVATION IN FEET—BOSTON CITY BASE
PROBABLE ROCK SURFACE
TUNNEL INVERT
PROFILE ALONG ACCEPTED TUNNEL LINE
WARE RIVER
SHAFT 8
PROBABLE ROCK SURFACE
PROBABLE ROCK SURFACE ALONG SOUTH LINE LOCATION
PROFILE ALONG ABANDONED TUNNEL LINE
LEGEND
BROKEN VERTICAL LINES INDICATE BORINGS OFF TUNNEL LINE.
FULL VERTICAL LINES INDICATE BORINGS ON TUNNEL LINE.
SOLID DOTS INDICATE BORINGS ON PLAN.
INDICATES SURFACE EXPOSURE OF ROCK.
GLACIAL DRIFT.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
WARE-PRINCE RIVER VALLEYS
SUB-SURFACE INVESTIGATIONS
800 400 0 800 1600 FT.
NOV. 6, 1930.

FIGURE 5

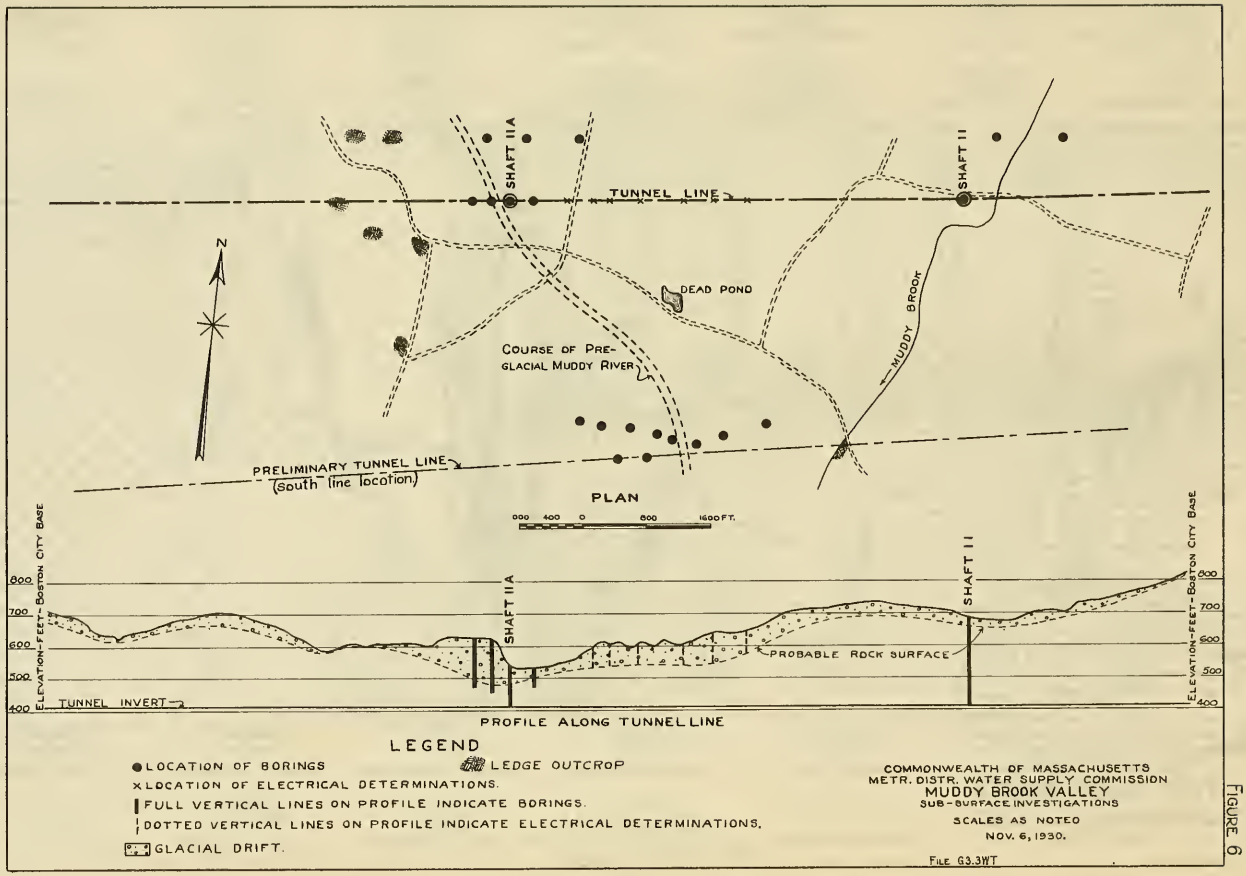

SHAFT 11A
SHAFT 11
TUNNEL LINE
DEAD POND
MUDDY BROOK
COURSE OF PRE-GLACIAL MUDDY RIVER
PRELIMINARY TUNNEL LINE (South line location)
N
PLAN
000 400 0 800 1600 FT.
ELEVATION-FEET-BOSTON CITY BASE
800
700
600
500
400
TUNNEL INVERT
PROBABLE ROCK SURFACE
PROFILE ALONG TUNNEL LINE
LEGEND
LOCATION OF BORINGS
LEDGE OUTCROP
LOCATION OF ELECTRICAL DETERMINATIONS.
FULL VERTICAL LINES ON PROFILE INDICATE BORINGS.
DOTTED VERTICAL LINES ON PROFILE INDICATE ELECTRICAL DETERMINATIONS.
GLACIAL DRIFT.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
MUDDY BROOK VALLEY
SUB-SURFACE INVESTIGATIONS
SCALES AS NOTED
NOV. 6, 1930.
FILE G3.3WT

FIGURE 6

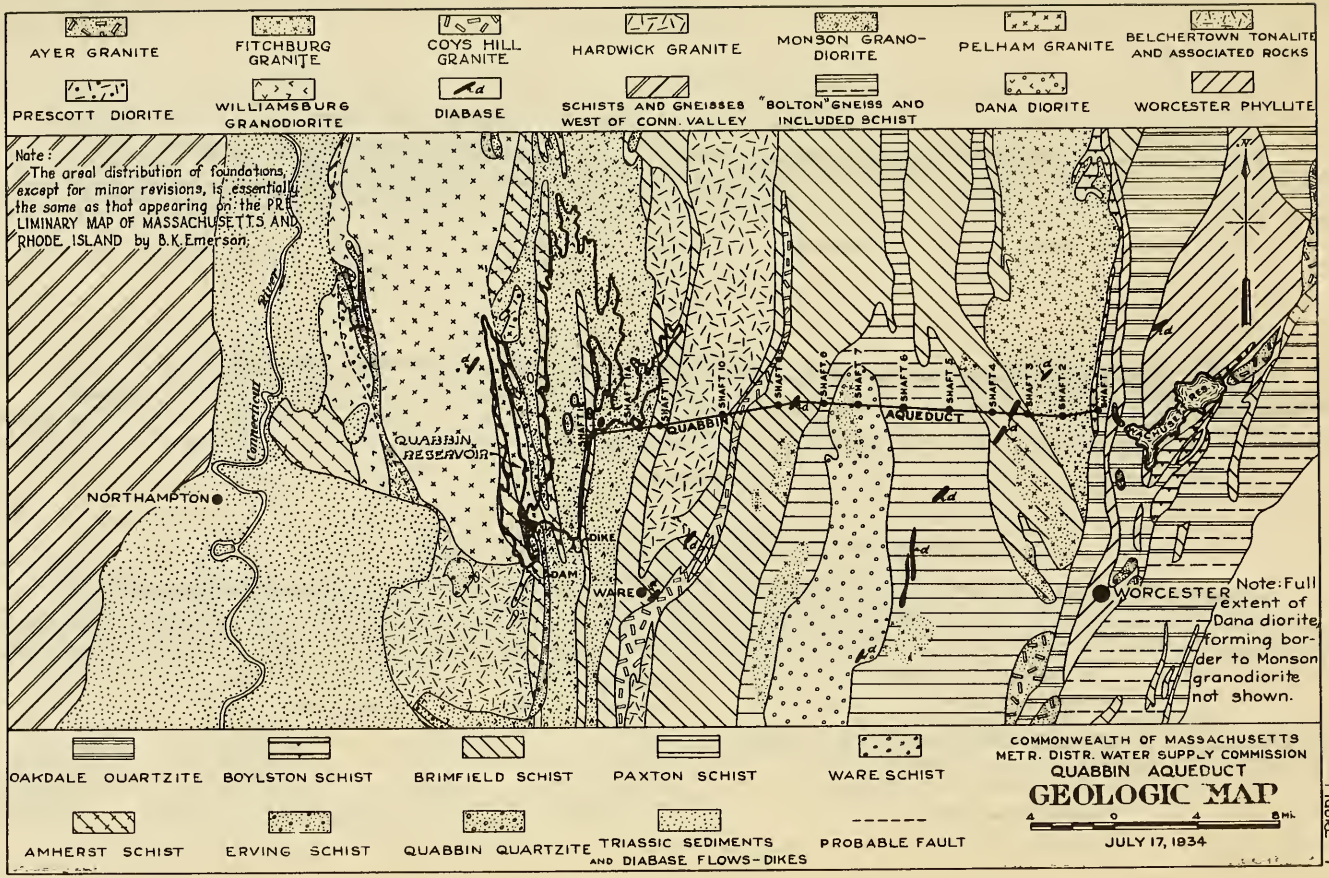

AYER GRANITE
FITCHBURG GRANITE
COYS HILL GRANITE
HARDWICK GRANITE
MONSON GRANO-DIORITE
PELHAM GRANITE
BELCHERTOWN TONALITE AND ASSOCIATED ROCKS
PRESCOTT DIORITE
WILLIAMSBURG GRANODIORITE
DIABASE
SCHISTS AND GNEISSES WEST OF CONN. VALLEY
"BOLTON" GNEISS AND INCLUDED SCHIST
DANA DIORITE
WORCESTER PHYLLITE
Note:
The areal distribution of foundations, except for minor revisions, is essentially the same as that appearing on the PRELIMINARY MAP OF MASSACHUSETTS AND RHODE ISLAND by B.K. Emerson.
CONNECTICUT RIVER
QUABBIN RESERVOIR
NORTHAMPTON
DIKE
DAM
WARE
QUABBIN
AQUEDUCT
WORCESTER
Note: Full extent of Dana diorite forming border to Monson granodiorite not shown.
OAKDALE QUARTZITE
BOYLSTON SCHIST
BRIMFIELD SCHIST
PAXTON SCHIST
WARE SCHIST
AMHERST SCHIST
ERVING SCHIST
QUABBIN QUARTZITE
TRIASSIC SEDIMENTS AND DIABASE FLOWS-DIKES
PROBABLE FAULT
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC MAP
4 0 4 8 MI.
JULY 17, 1934

FIGURE 7

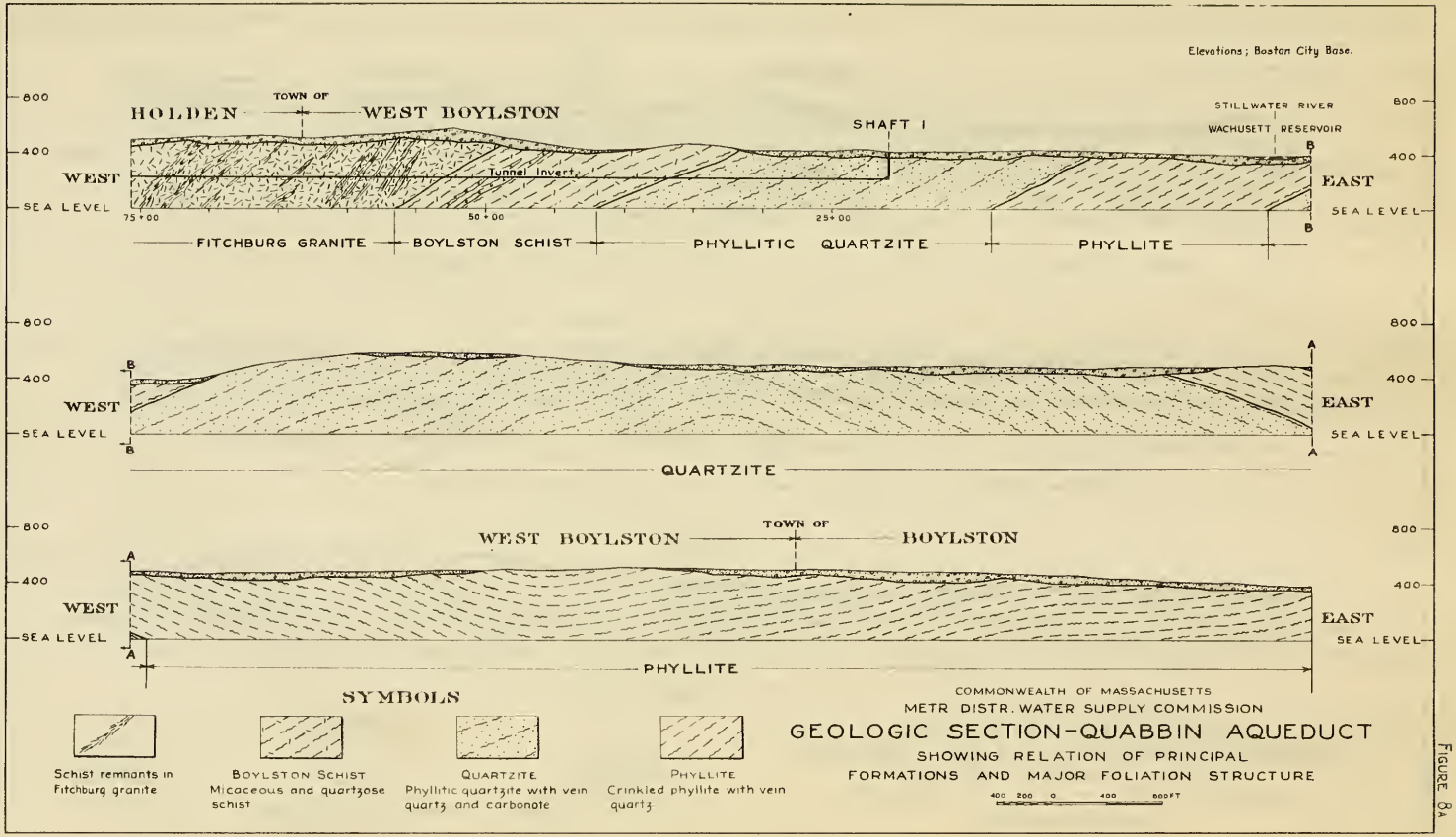

Elevations; Boston City Base.
800
400
SEA LEVEL
HOLDEN
TOWN OF
WEST BOYLSTON
SHAFT I
STILLWATER RIVER
WACHUSETT RESERVOIR
WEST
EAST
Tunnel Invert
75+00
50+00
25+00
FITCHBURG GRANITE
BOYLSTON SCHIST
PHYLLITIC QUARTZITE
PHYLLITE
QUARTZITE
WEST BOYLSTON
TOWN OF
BOYLSTON
SYMBOLS
Schist remnants in Fitchburg granite
BOYLSTON SCHIST
Micaceous and quartzose schist
QUARTZITE
Phyllitic quartzite with vein quartz and carbonate
PHYLLITE
Crinkled phyllite with vein quartz
COMMONWEALTH OF MASSACHUSETTS
METR DISTR. WATER SUPPLY COMMISSION
GEOLOGIC SECTION-QUABBIN AQUEDUCT
SHOWING RELATION OF PRINCIPAL
FORMATIONS AND MAJOR FOLIATION STRUCTURE
400 200 0 400 800 FT

FIGURE 8A

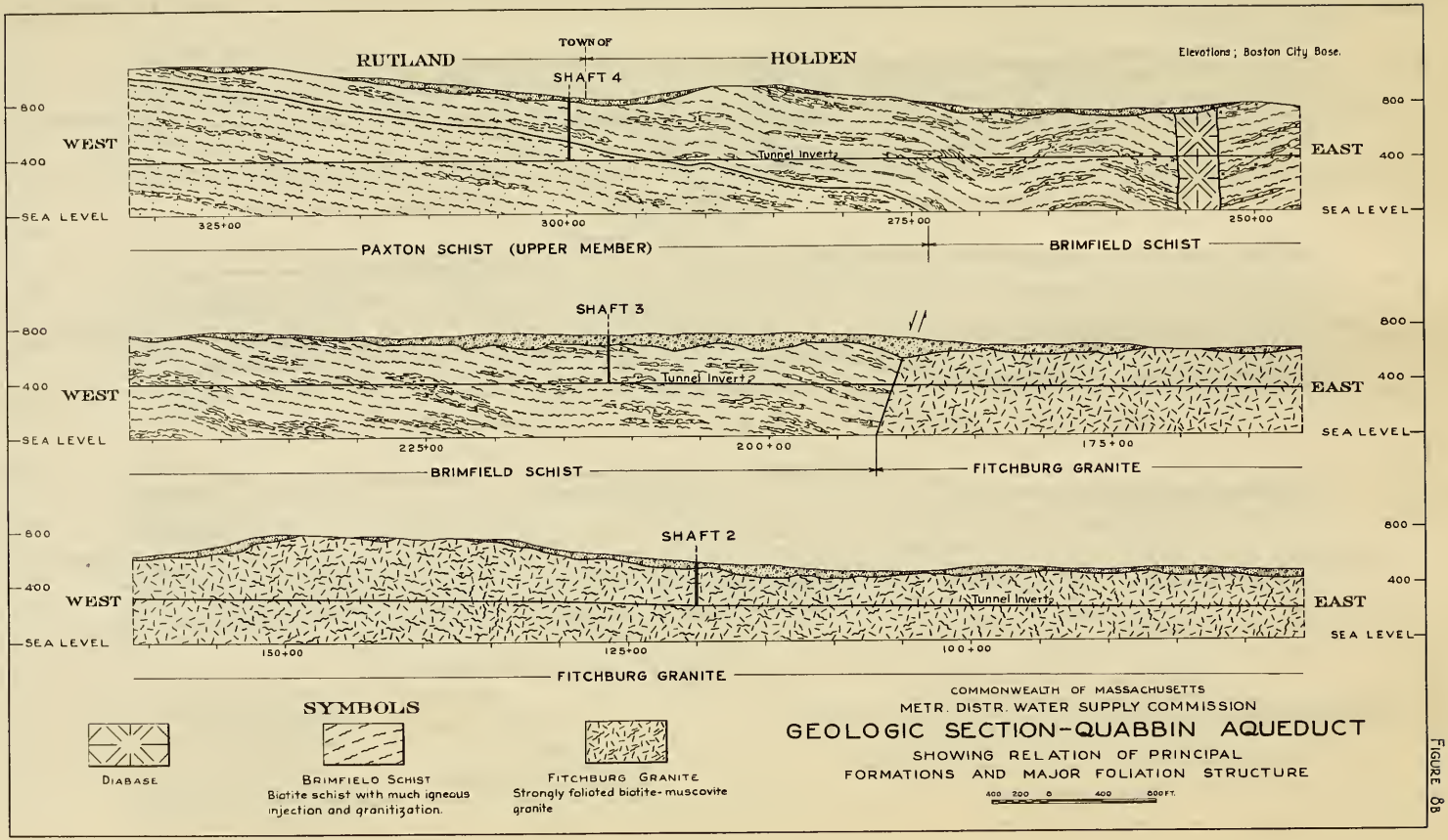

TOWN OF
RUTLAND
HOLDEN
Elevations; Boston City Base.
SHAFT 4
800
400
SEA LEVEL
WEST
EAST
Tunnel Invert?
325+00
300+00
275+00
250+00
PAXTON SCHIST (UPPER MEMBER)
BRIMFIELD SCHIST
SHAFT 3
225+00
200+00
175+00
BRIMFIELD SCHIST
FITCHBURG GRANITE
SHAFT 2
150+00
125+00
100+00
FITCHBURG GRANITE
SYMBOLS
DIABASE
BRIMFIELD SCHIST
Biotite schist with much igneous injection and granitization.
FITCHBURG GRANITE
Strongly foliated biotite-muscovite granite
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
GEOLOGIC SECTION-QUABBIN AQUEDUCT
SHOWING RELATION OF PRINCIPAL
FORMATIONS AND MAJOR FOLIATION STRUCTURE
400 200 0 400 800 FT.

FIGURE 88

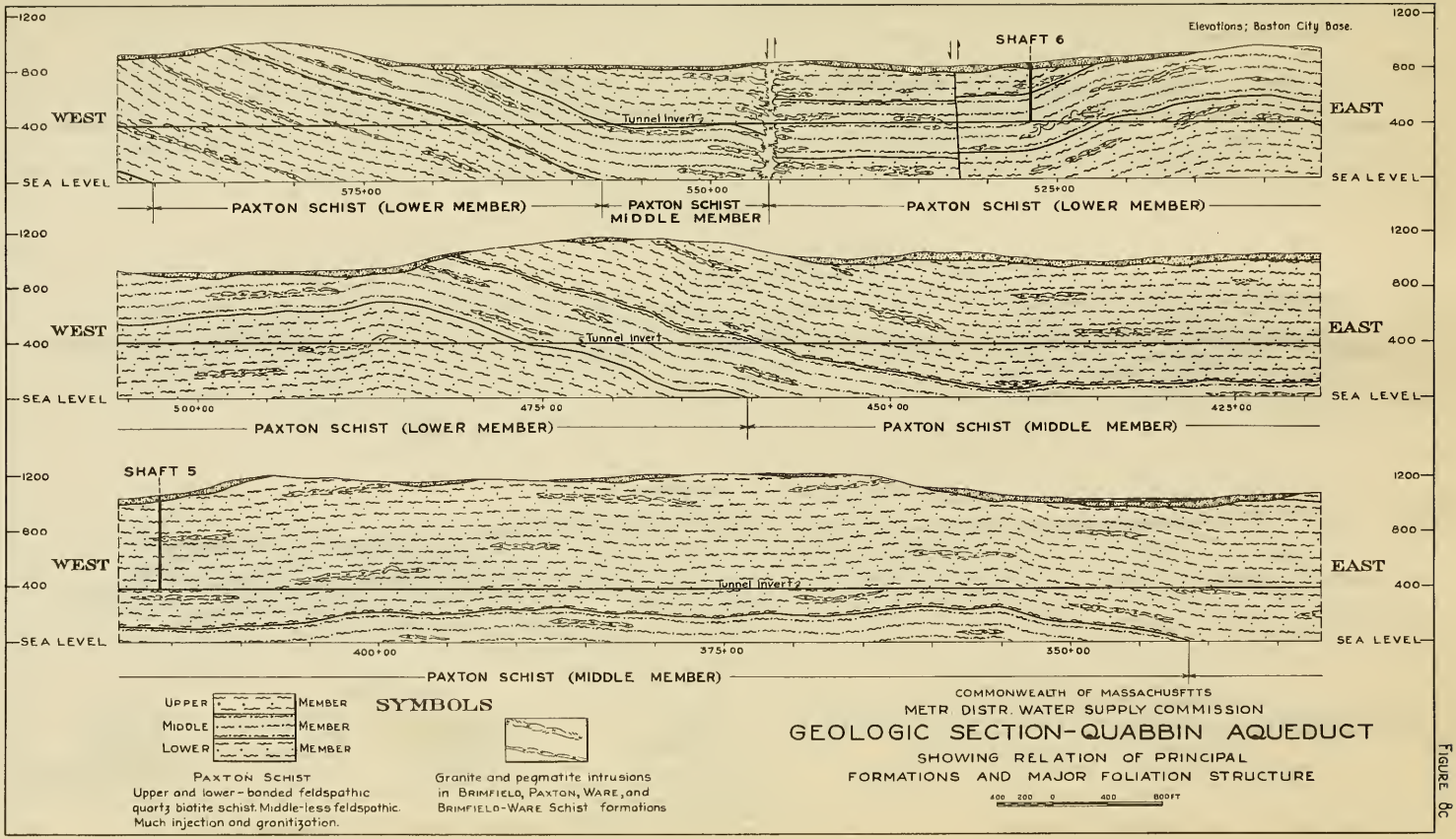

Elevations; Boston City Base.
SHAFT 6
WEST
EAST
1200
800
400
SEA LEVEL
Tunnel Invert
575+00
550+00
525+00
PAXTON SCHIST (LOWER MEMBER)
PAXTON SCHIST MIDDLE MEMBER
PAXTON SCHIST (LOWER MEMBER)
500+00
475+00
450+00
425+00
PAXTON SCHIST (LOWER MEMBER)
PAXTON SCHIST (MIDDLE MEMBER)
SHAFT 5
400+00
375+00
350+00
PAXTON SCHIST (MIDDLE MEMBER)
UPPER MEMBER
MIDDLE MEMBER
LOWER MEMBER
SYMBOLS
PAXTON SCHIST
Upper and lower-banded feldspathic quartz biotite schist. Middle-less feldspathic. Much injection and granitization.
Granite and pegmatite intrusions in BRIMFIELD, PAXTON, WARE, and BRIMFIELD-WARE Schist formations
COMMONWEALTH OF MASSACHUSETTS
METR DISTR. WATER SUPPLY COMMISSION
GEOLOGIC SECTION-QUABBIN AQUEDUCT
SHOWING RELATION OF PRINCIPAL FORMATIONS AND MAJOR FOLIATION STRUCTURE
400 200 0 400 800 FT

FIGURE 8C

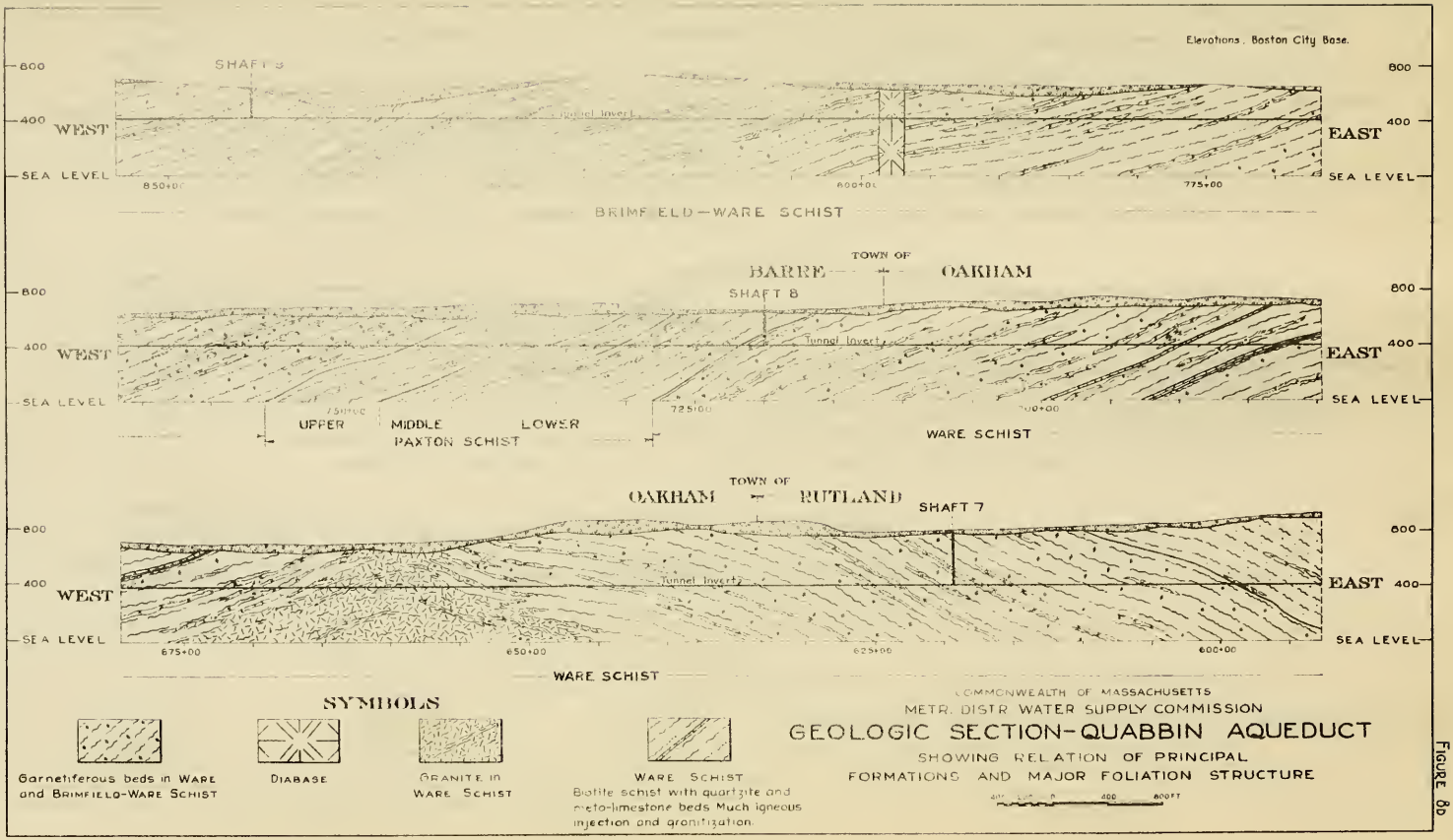

Elevations. Boston City Base.
800
400
SEA LEVEL
WEST
EAST
SHAFT 9
Tunnel Invert
850+00
800+00
775+00
BRIMFIELD—WARE SCHIST
TOWN OF
BARRE
OAKHAM
SHAFT 8
Tunnel Invert
725+00
700+00
UPPER
MIDDLE
LOWER
PAXTON SCHIST
WARE SCHIST
TOWN OF
OAKHAM
RUTLAND
SHAFT 7
Tunnel Invert
675+00
650+00
625+00
600+00
WARE SCHIST
SYMBOLS
Garnetiferous beds in WARE and BRIMFIELD-WARE SCHIST
DIABASE
GRANITE in WARE SCHIST
WARE SCHIST
Biotite schist with quartzite and meta-limestone beds. Much igneous injection and granitization.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
GEOLOGIC SECTION-QUABBIN AQUEDUCT
SHOWING RELATION OF PRINCIPAL FORMATIONS AND MAJOR FOLIATION STRUCTURE
400
800 FT

FIGURE 8b

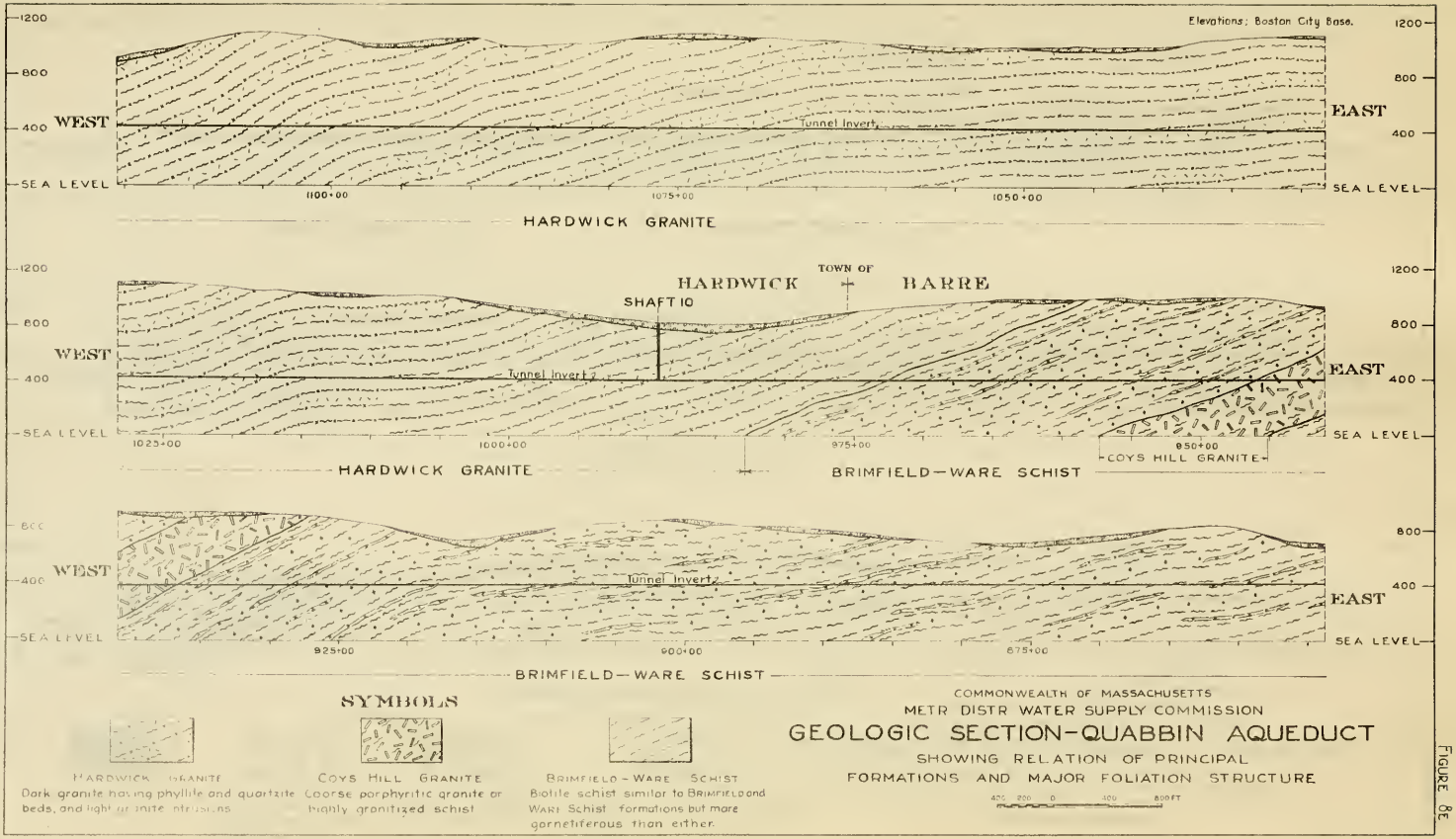
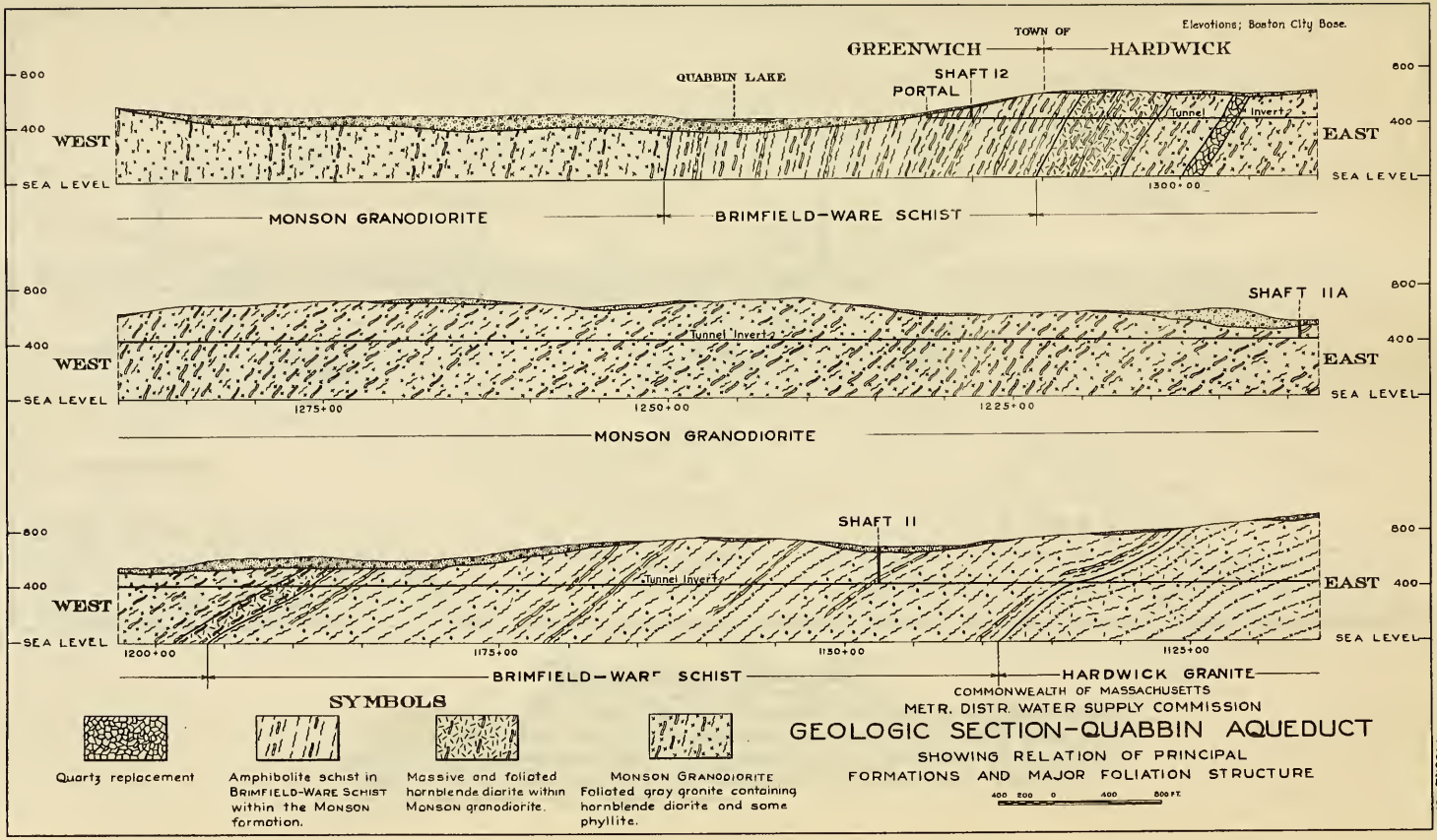

Elevations; Boston City Base.
1200
800
400
SEA LEVEL
WEST
EAST
Tunnel Invert
1100+00
1075+00
1050+00
HARDWICK GRANITE
TOWN OF
HARDWICK
BARRE
SHAFT 10
1025+00
1000+00
975+00
950+00
COYS HILL GRANITE
BRIMFIELD—WARE SCHIST
925+00
900+00
875+00
SYMBOLS
HARDWICK GRANITE
Dark granite having phyllite and quartzite beds, and light granite intrusions
COYS HILL GRANITE
Coarse porphyritic granite or highly granitized schist
BRIMFIELD-WARE SCHIST
Biotite schist similar to BRIMFIELD and WARE Schist formations but more garnetiferous than either.
COMMONWEALTH OF MASSACHUSETTS
METR DISTR WATER SUPPLY COMMISSION
GEOLOGIC SECTION-QUABBIN AQUEDUCT
SHOWING RELATION OF PRINCIPAL
FORMATIONS AND MAJOR FOLIATION STRUCTURE
400 200 0 400 800 FT

FIGURE 8E

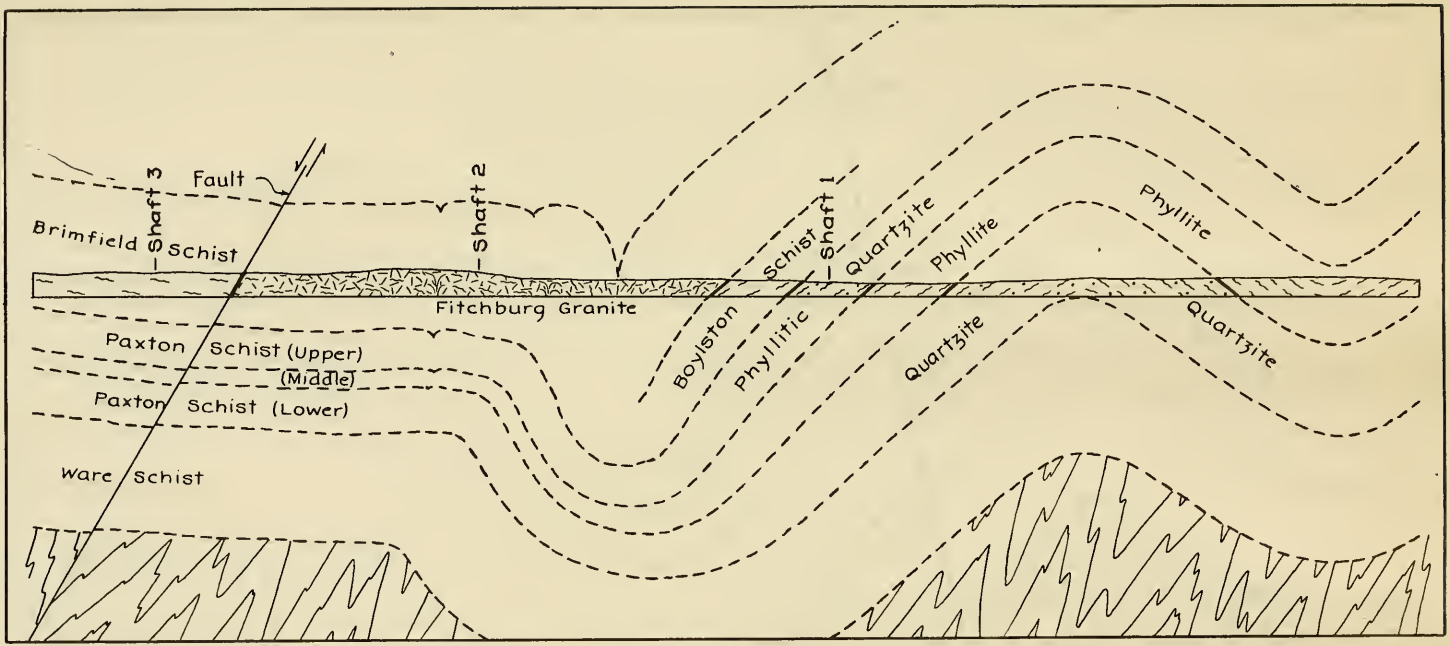


COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION

GEOLOGIC SECTION-QUABBIN AQUEDUCT

SHOWING RELATION OF PRINCIPAL FORMATIONS AND MAJOR FOLIATION STRUCTURE

FIGURE 8F

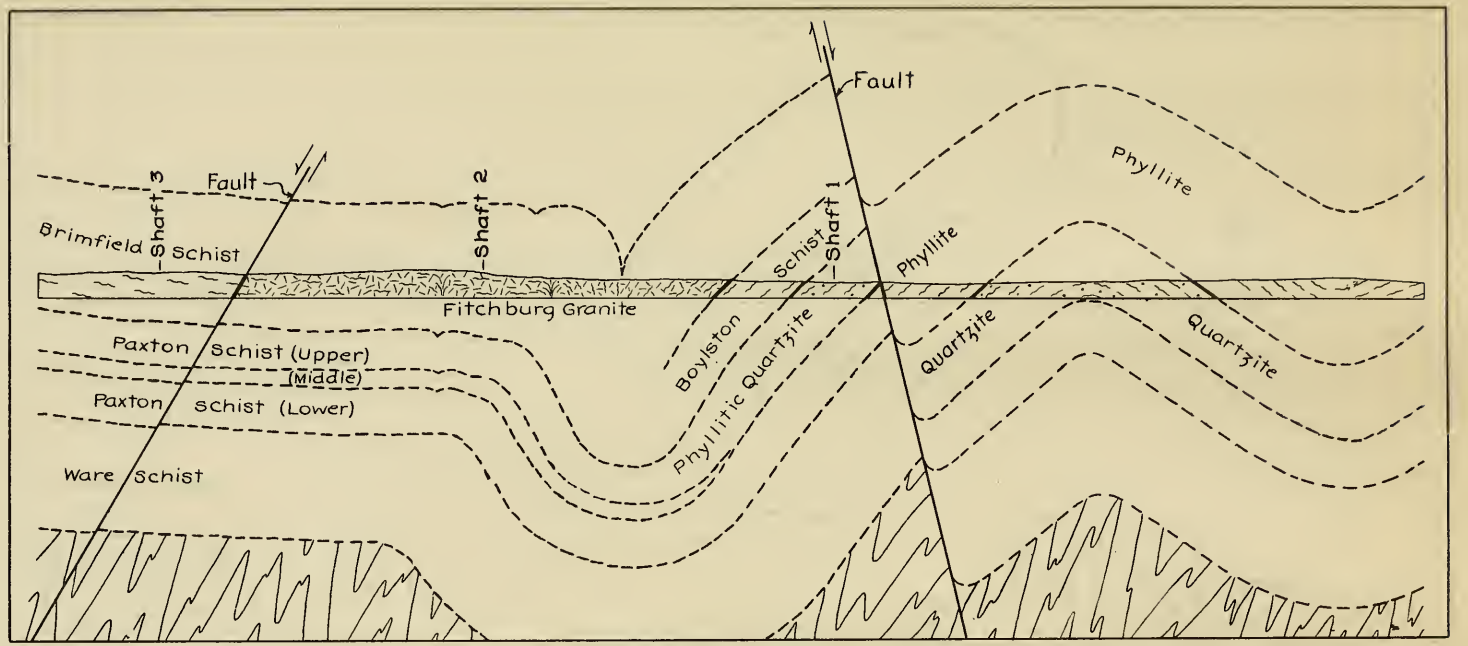


3000 0 3000 6000 FT.

HORIZONTAL AND VERTICAL SCALE

Diagramatic sketch illustrating an alternative interpretation of the structural attitude of formations based on the assumption that rocks are all of the same age; that the phyllite and quartzite of the geologic section are parts of the Worcester phyllite and Oakdale quartzite formations, and that they grade laterally into the schists, which occur farther west.

FIGURE 9

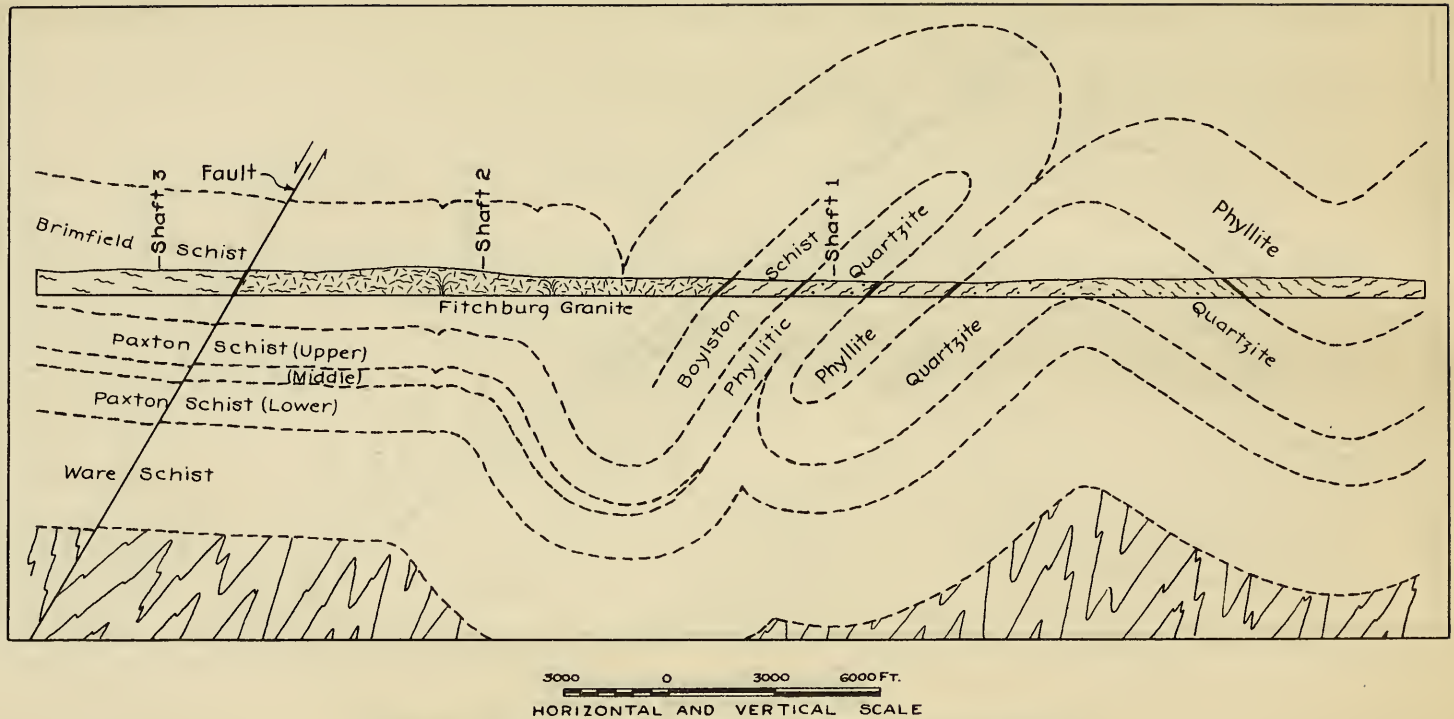


3000 0 3000 6000 FT.

HORIZONTAL AND VERTICAL SCALE

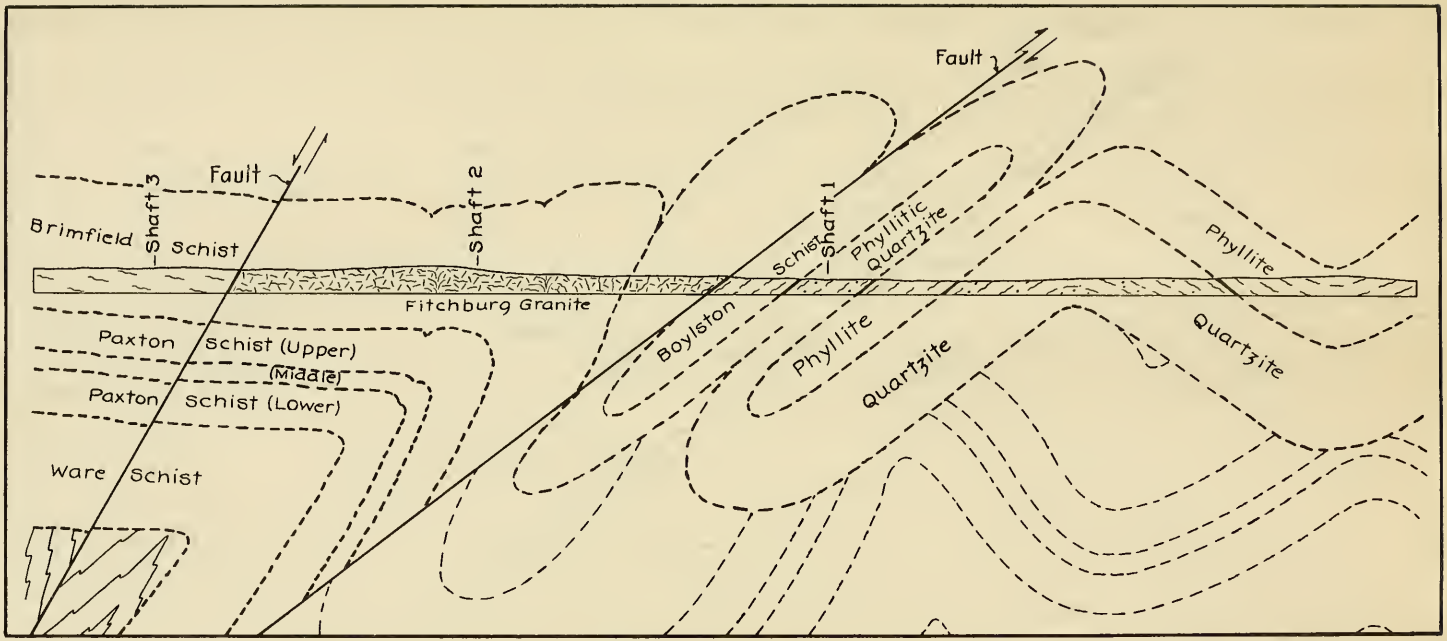
Diagramatic sketch or generalized section intended to illustrate an alternative interpretation of the stratigraphic relations based on the assumption that the formations are all of the same age; that phyllite and quartzite grade laterally into the schists which occur farther west, and that the whole series is normal faulted on the east.

FIGURE 10



Diagramatic sketch showing an alternative interpretation of the stratigraphic relations of formations based on the assumption that the strata are of the same age and that their structural attitude is the result of close folding which preceded or accompanied the Fitchburg granite invasion.

FIGURE 11

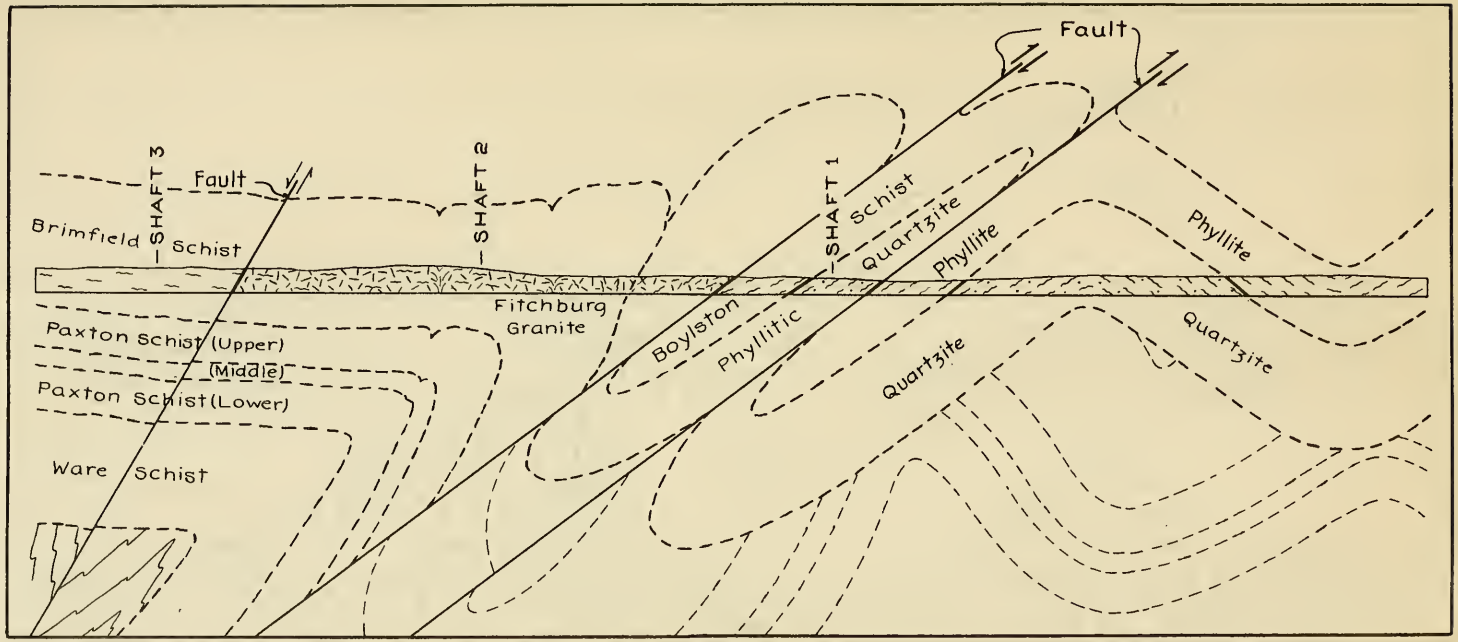


3000 0 3000 6000 FT.

HORIZONTAL AND VERTICAL SCALE

Generalized section showing the structural attitude drawn on the assumption that the schists are older than the phyllite and quartzite and have been displaced by thrust faulting. This interpretation regards the phyllite and quartzite as crowded, crumpled and overridden by the older schists. It is assumed that these movements preceded or were accompanied by the Fitchburg granite invasion which destroyed most of the structural evidence.

FIGURE 12

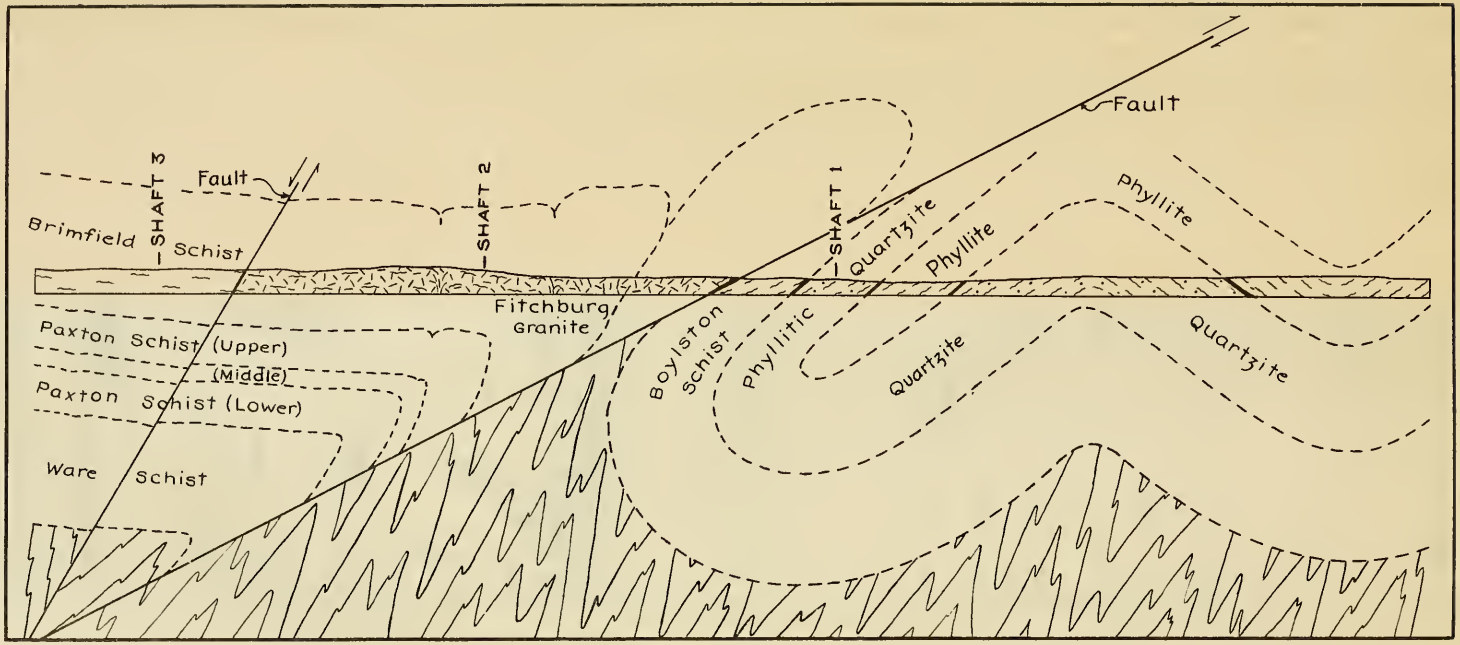


3000 0 3000 6000 FT.

HORIZONTAL AND VERTICAL SCALE

Diagramatic sketch showing an alternative interpretation of the structural relation of formations based on the assumption that the schist rocks of the western area represent a series of ancient sediments which have been thrust over the much younger phyllite and quartzite strata. This explanation differs only in the detail of faulting from the preceding.

FIGURE 13



3000 0 3000 6000 FT.

HORIZONTAL AND VERTICAL SCALE

Diagramatic sketch showing an alternative interpretation based on different age relations for the Carboniferous phyllite of the Worcester "coal mine", the schists and the Fitchburg granite. The interpretation assumes that the schist strata were metamorphosed, deformed and intruded by granite before the Carboniferous period.

FIGURE 14

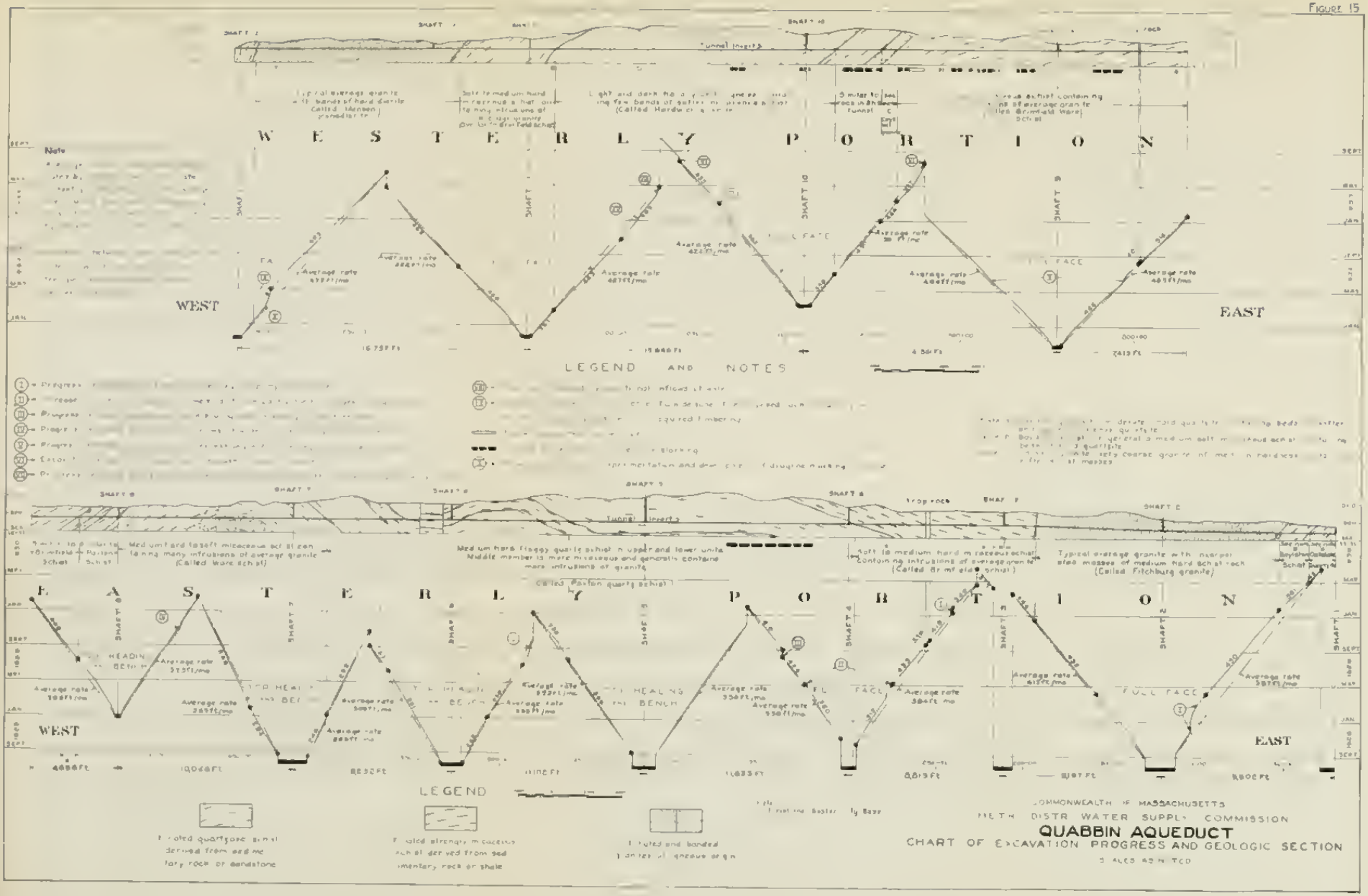
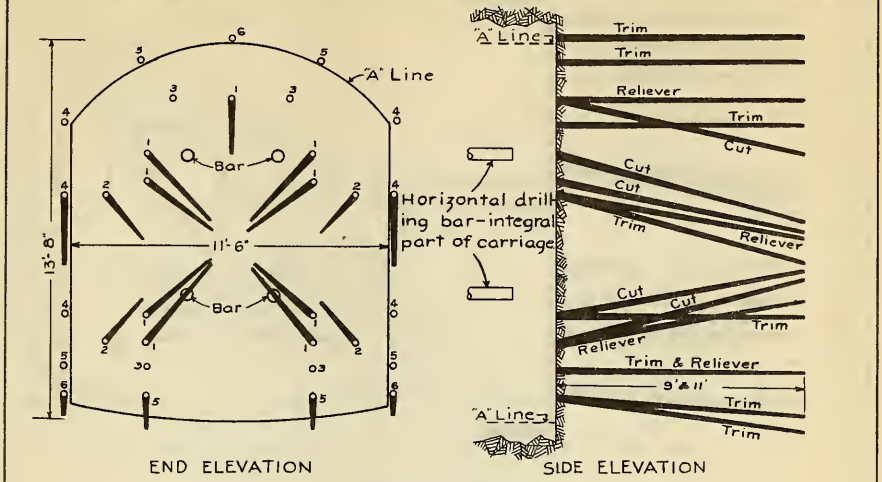

WESTERLY PORTION
WEST
EAST
LEGEND AND NOTES
EASTERLY PORTION
WEST
EAST
LEGEND
COMMONWEALTH OF MASSACHUSETTS
METROPOLITAN WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
CHART OF EXCAVATION PROGRESS AND GEOLOGIC SECTION

FIGURE 16



The numbers indicate the order of firing by delayed timing.

DIAGRAM SHOWING LOCATION OF DRILL HOLES IN FULL HEADINGS AT SHAFT 11

16b

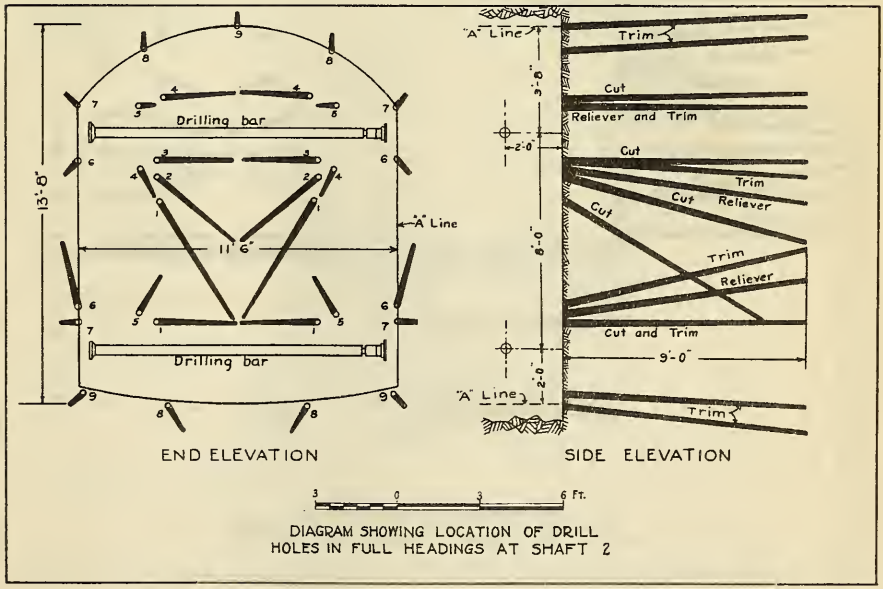
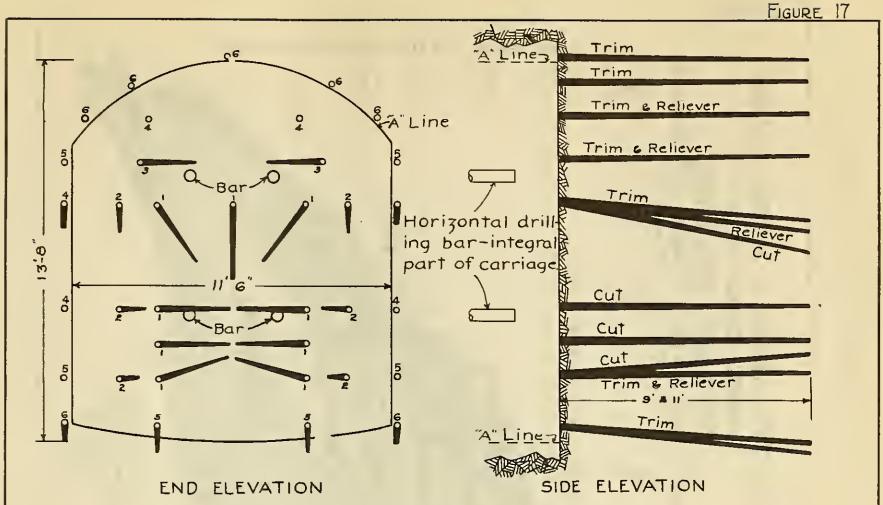


DIAGRAM SHOWING LOCATION OF DRILL HOLES IN FULL HEADINGS AT SHAFT 2

FIGURE 17



The numbers indicate the order of firing by delayed timing.
DIAGRAM SHOWING LOCATION OF DRILL HOLES IN FULL HEADINGS AT SHAFT 12

17b

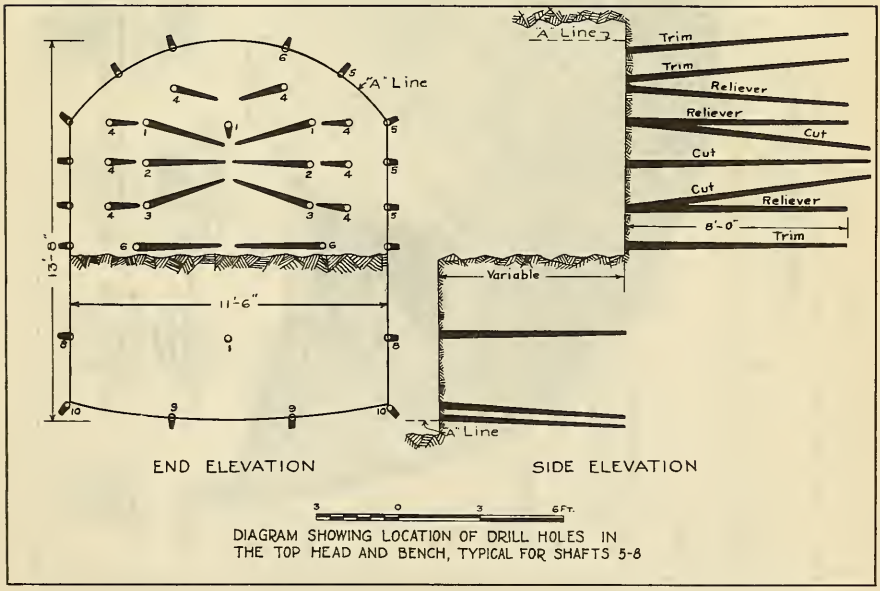
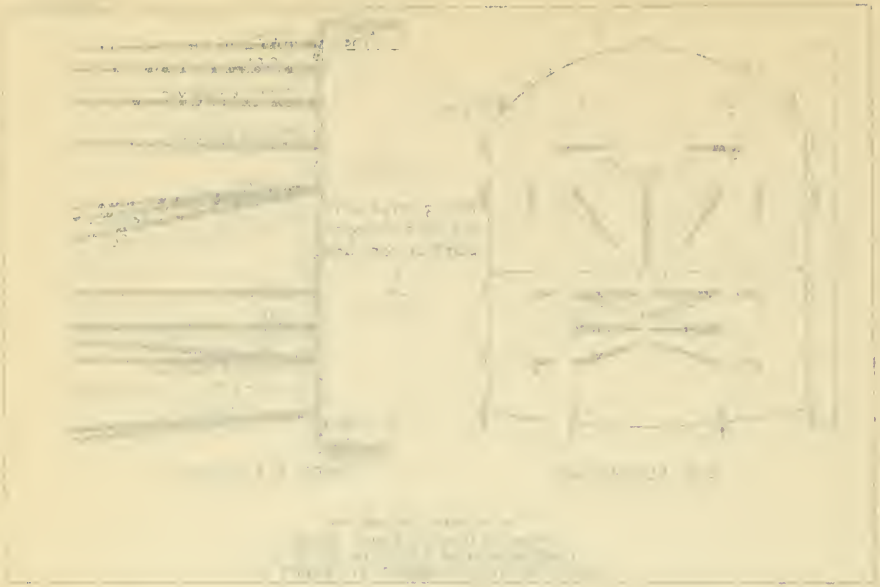
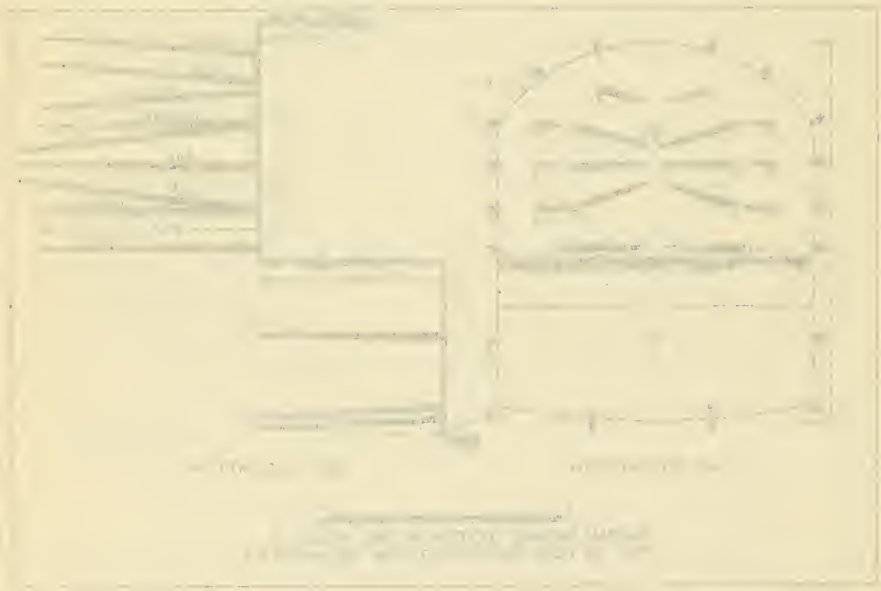


DIAGRAM SHOWING LOCATION OF DRILL HOLES IN THE TOP HEAD AND BENCH, TYPICAL FOR SHAFTS 5-8





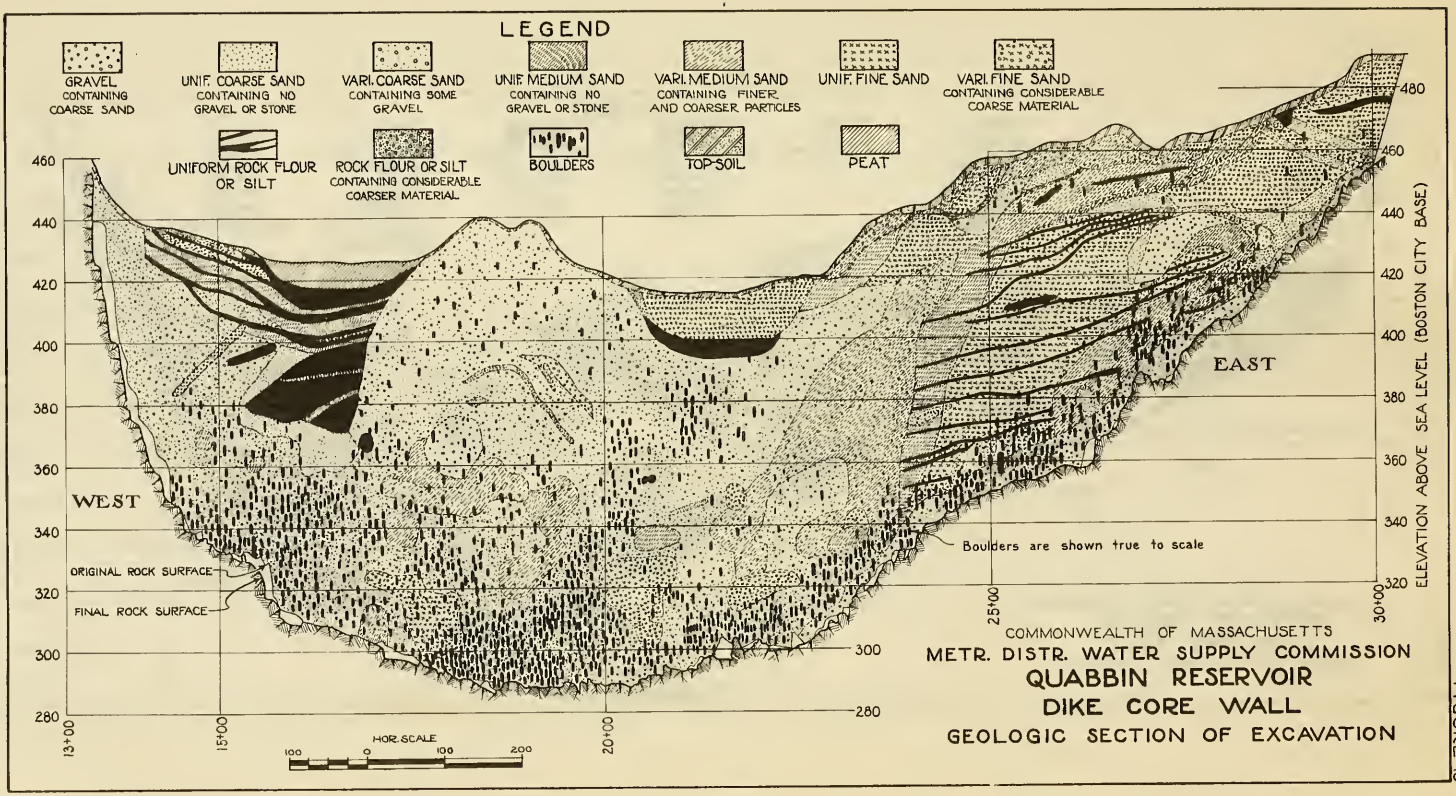

LEGEND
GRAVEL CONTAINING COARSE SAND
UNIF. COARSE SAND CONTAINING NO GRAVEL OR STONE
VARI. COARSE SAND CONTAINING SOME GRAVEL
UNIF. MEDIUM SAND CONTAINING NO GRAVEL OR STONE
VARI. MEDIUM SAND CONTAINING FINER AND COARSER PARTICLES
UNIF. FINE SAND
VARI. FINE SAND CONTAINING CONSIDERABLE COARSE MATERIAL
UNIFORM ROCK FLOUR OR SILT
ROCK FLOUR OR SILT CONTAINING CONSIDERABLE COARSER MATERIAL
BOULDERS
TOP-SOIL
PEAT
WEST
EAST
ORIGINAL ROCK SURFACE
FINAL ROCK SURFACE
Boulders are shown true to scale
ELEVATION ABOVE SEA LEVEL (BOSTON CITY BASE)
460
440
420
400
380
360
340
320
300
280
480
13+00
15+00
20+00
25+00
30+00
HOR. SCALE
100
0
100
200
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN RESERVOIR
DIKE CORE WALL
GEOLOGIC SECTION OF EXCAVATION

FIGURE 18

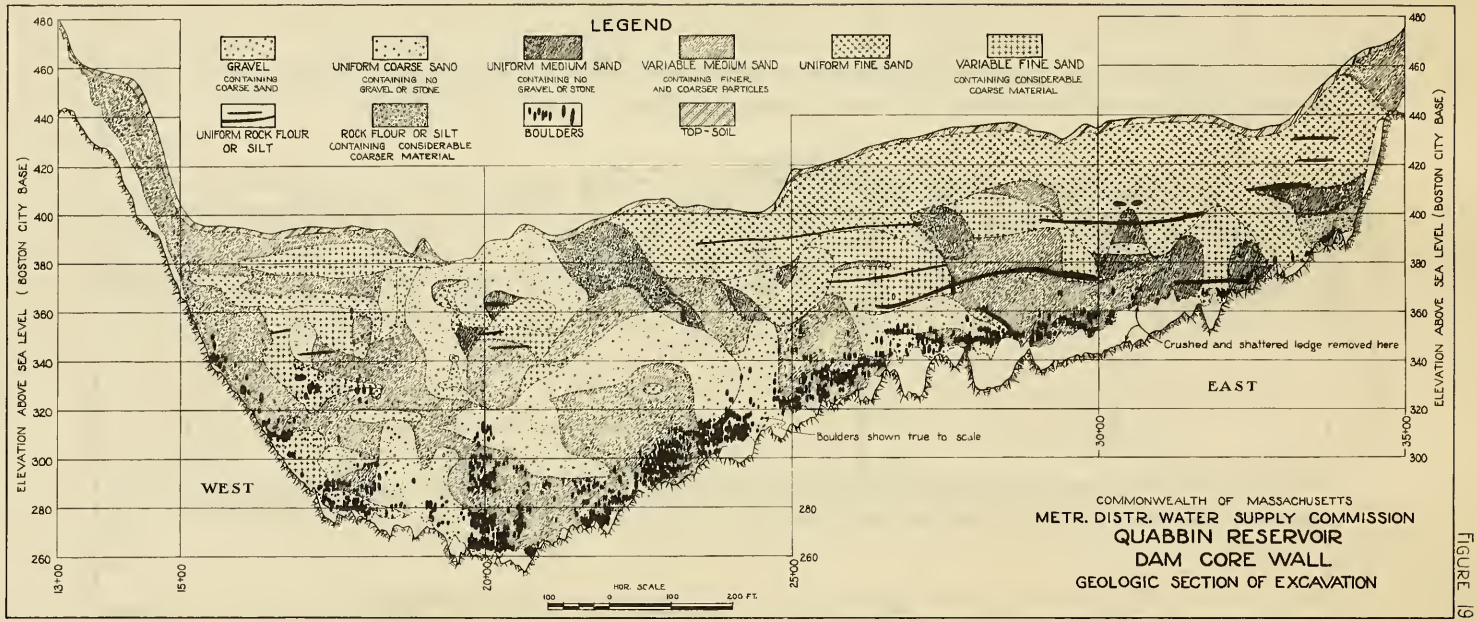
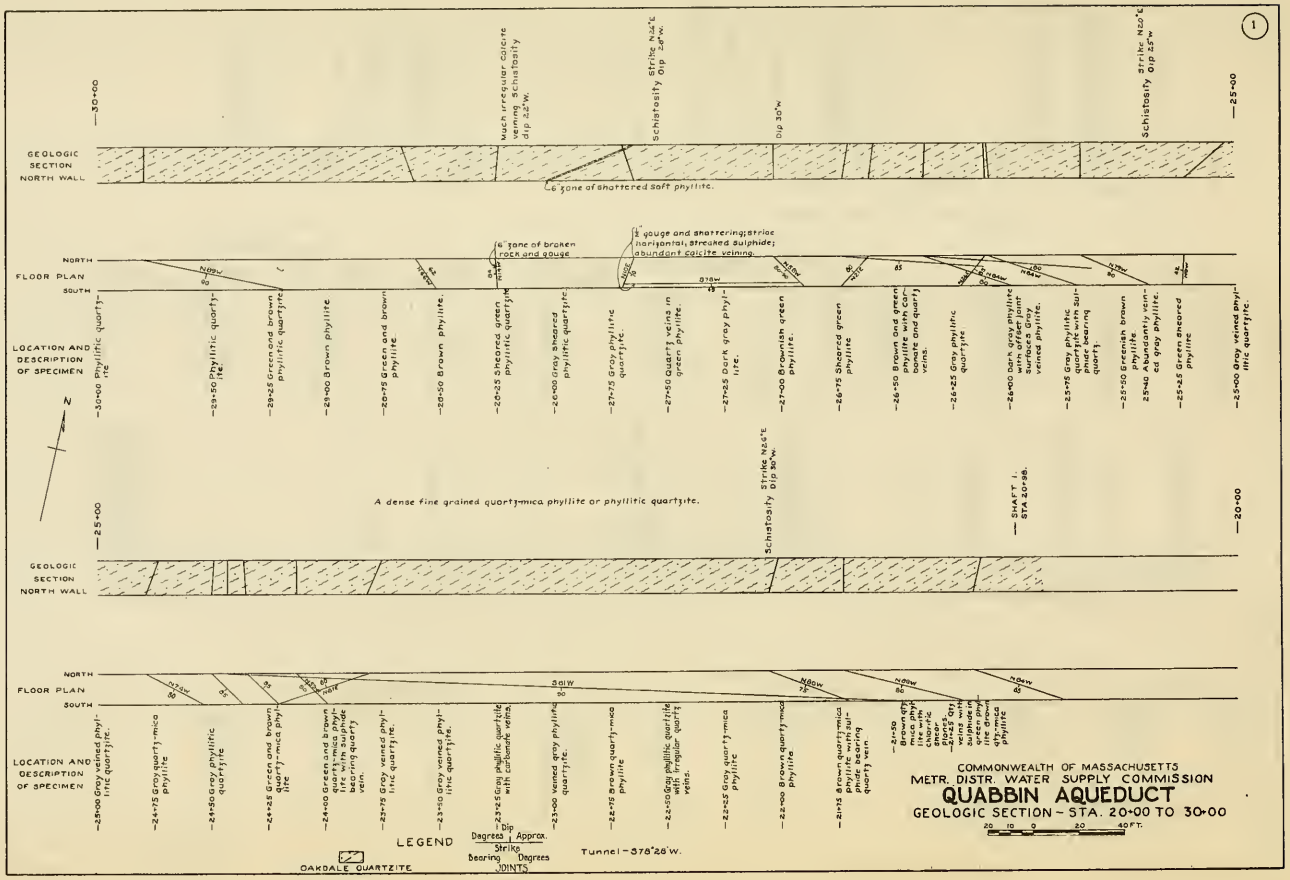
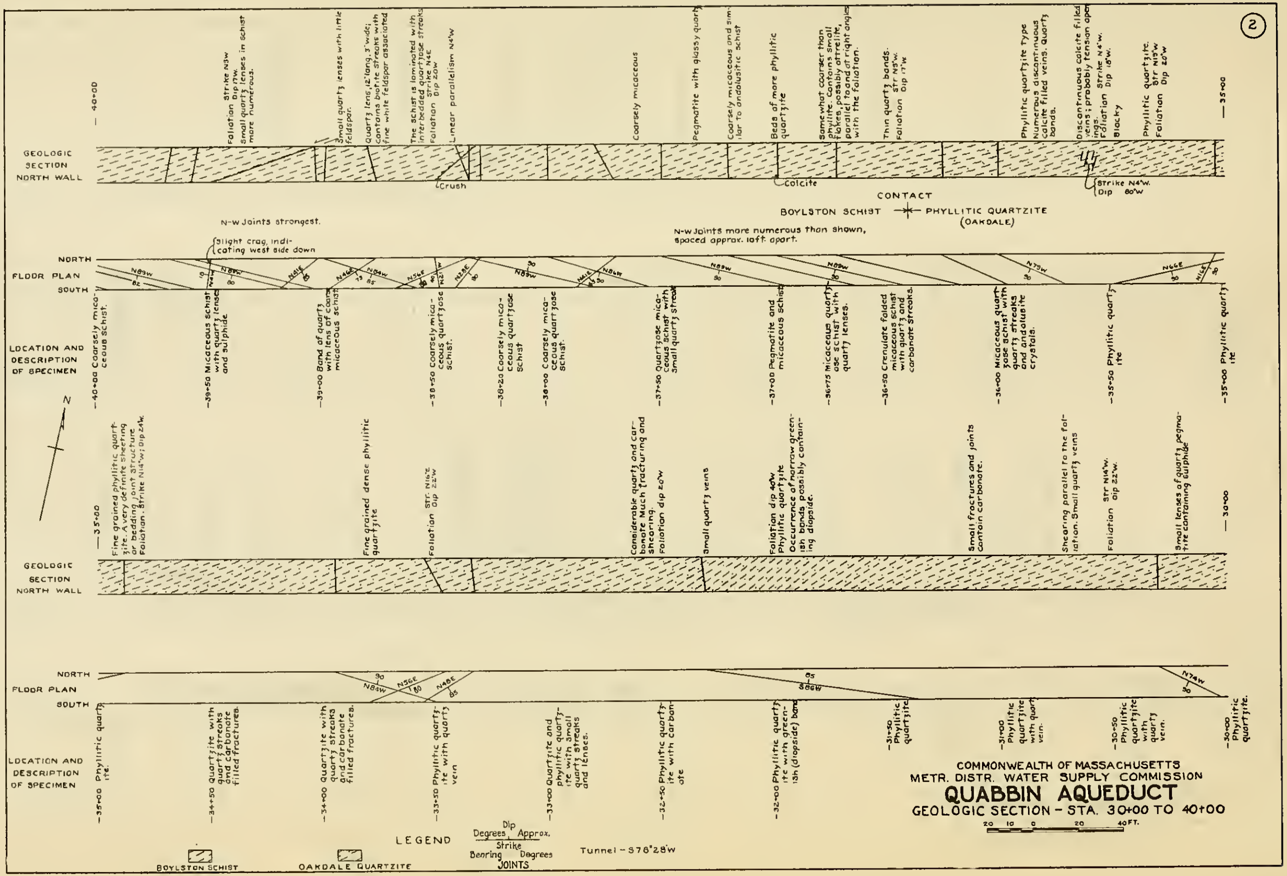
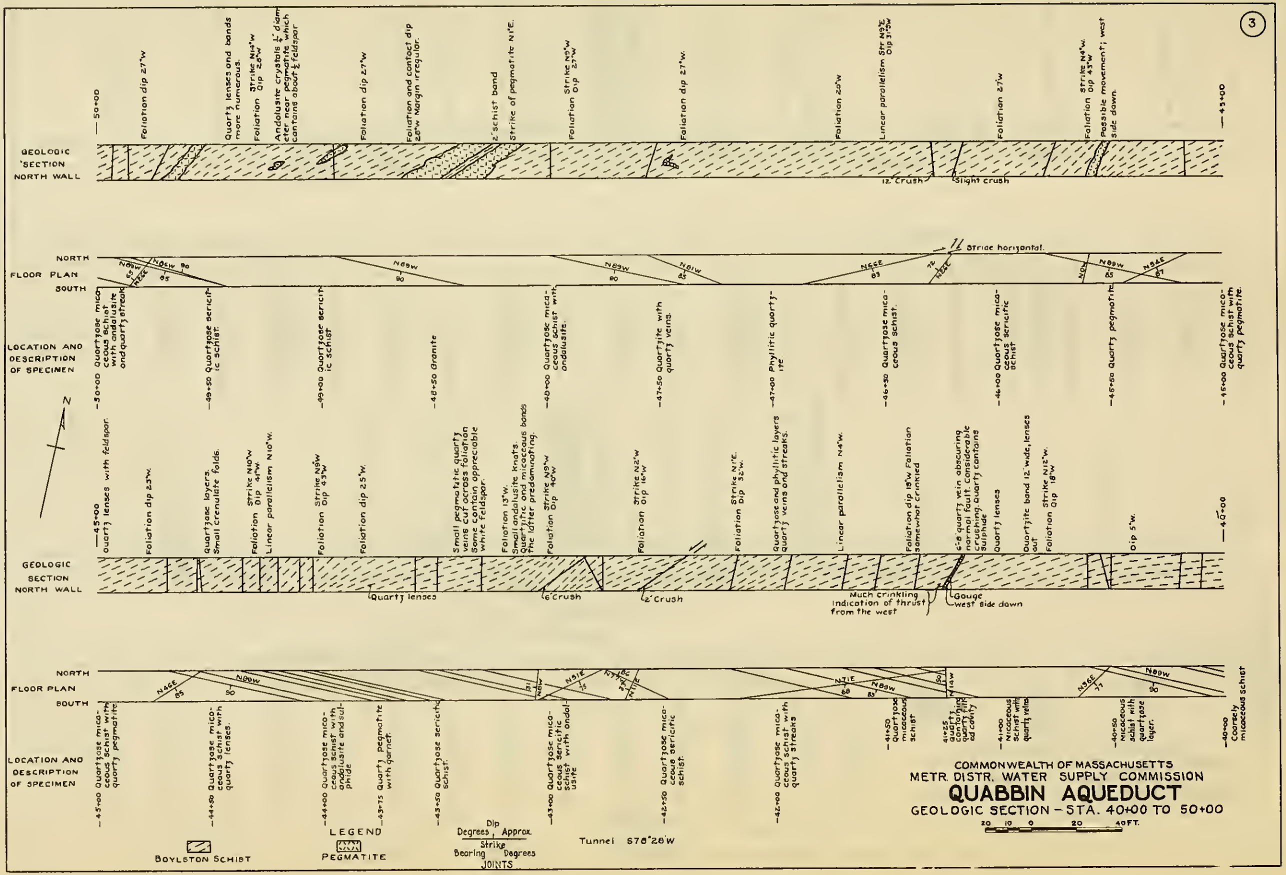
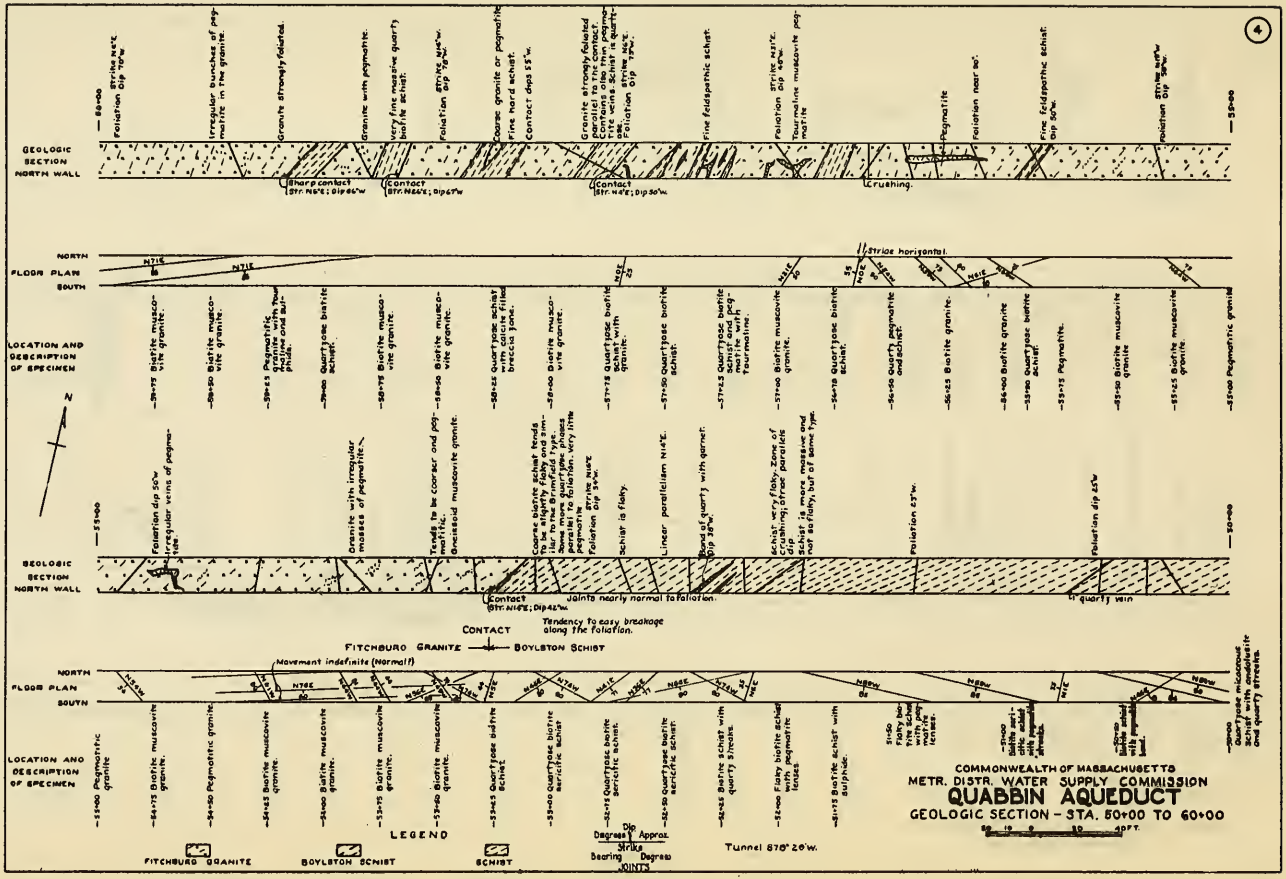

LEGEND
GRAVEL
CONTAINING COARSE SAND
UNIFORM COARSE SAND
CONTAINING NO GRAVEL OR STONE
UNIFORM MEDIUM SAND
CONTAINING NO GRAVEL OR STONE
VARIABLE MEDIUM SAND
CONTAINING FINER AND COARSER PARTICLES
UNIFORM FINE SAND
VARIABLE FINE SAND
CONTAINING CONSIDERABLE COARSE MATERIAL
UNIFORM ROCK FLOUR OR SILT
ROCK FLOUR OR SILT
CONTAINING CONSIDERABLE COARSER MATERIAL
BOULDERS
TOP-SOIL
ELEVATION ABOVE SEA LEVEL (BOSTON CITY BASE)
480
460
440
420
400
380
360
340
320
300
280
260
13+00
15+00
20+00
25+00
30+00
35+00
WEST
EAST
Boulders shown true to scale
Crushed and shattered ledge removed here
HOR. SCALE
100 0 100 200 FT.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN RESERVOIR
DAM CORE WALL
GEOLOGIC SECTION OF EXCAVATION

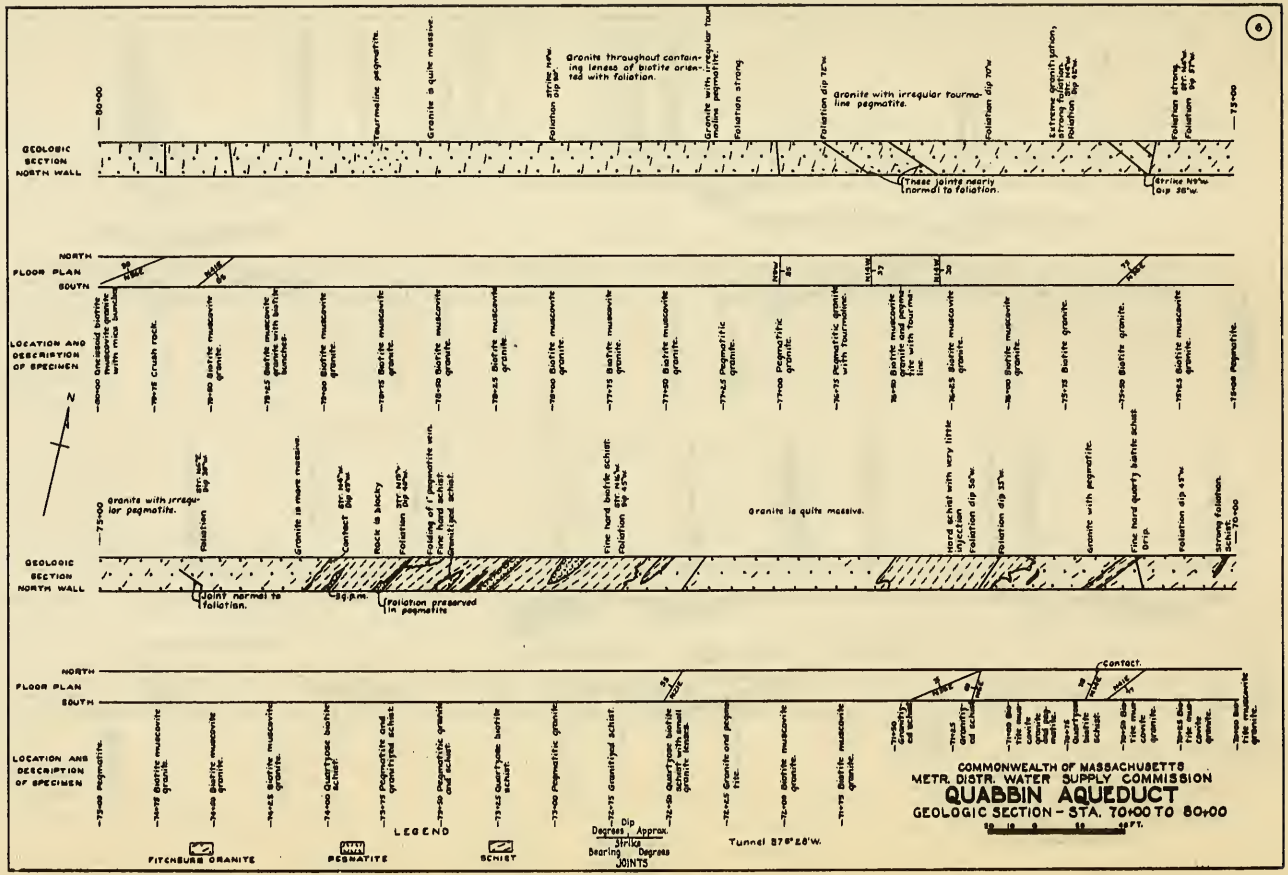
FIGURE 19

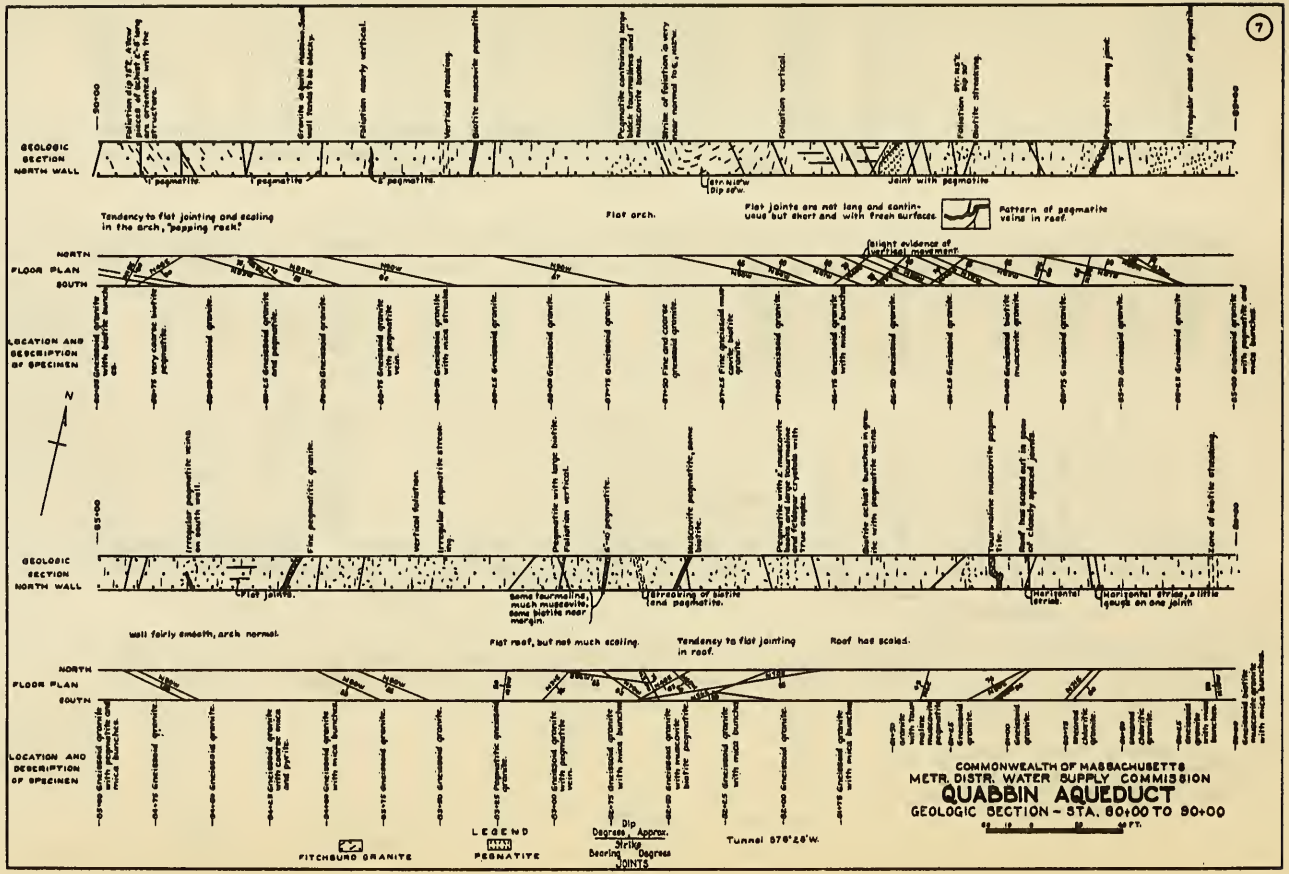

1
GEOLOGIC SECTION NORTH WALL
30+00
much irregular calcite veining. Schistosity strike
dip 22°W.
Schistosity strike N 24°E
Dip 28°W.
dip 30°W
Schistosity strike N 20°E
Dip 25°W
25+00
6" zone of shattered soft phyllite.
FLOOR PLAN
NORTH
SOUTH
6" zone of broken rock and gouge
1" gouge and shattering; strike horizontal, streaked sulphide; abundant calcite veining.
LOCATION AND DESCRIPTION OF SPECIMEN
30+00 Phyllitic quartzite
29+50 Phyllitic quartzite
29+25 Green and brown phyllitic quartzite
29+00 Brown phyllite
28+75 Green and brown phyllite
28+50 Brown phyllite.
28+25 Sheared green phyllitic quartzite
26+00 Gray sheared phyllitic quartzite.
27+75 Gray phyllitic quartzite.
27+50 Quartz veins in green phyllite.
27+25 Dark gray phyllite.
27+00 Brownish green phyllite.
26+75 Sheared green phyllite
26+50 Brown and green phyllite with carbonate and quartz veins.
26+25 Gray phyllitic quartzite.
26+00 Dark gray phyllite with offset joint surfaces. Gray veined phyllite.
25+75 Gray phyllitic quartzite with sulphide bearing quartz.
25+50 Greenish brown phyllite.
25+40 Abundantly veined gray phyllite.
25+25 Green sheared phyllite
25+00 Gray veined phyllitic quartzite.
N
25+00
20+00
A dense fine grained quartz-mica phyllite or phyllitic quartzite.
Schistosity strike N 26°E dip 30°W.
SHAFT I. STA 20+86.
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
25+00 Gray veined phyllitic quartzite.
24+75 Gray quartz-mica phyllite
24+50 Gray phyllitic quartzite
24+25 Green and brown quartz-mica phyllite
24+00 Green and brown phyllite with sulphide bearing quartz veins
23+75 Gray veined phyllitic quartzite.
23+50 Gray veined phyllitic quartzite.
23+25 Gray phyllitic quartzite with carbonate veins.
23+00 veined gray phyllitic quartzite.
22+75 brown quartz-mica phyllite
22+50 Gray phyllitic quartzite with irregular quartz veins.
22+25 Gray quartz-mica phyllite
22+00 Brown quartz-mica phyllite.
21+75 Brown quartz-mica phyllite with sulphide bearing quartz veins.
21+50 Brownish green phyllite. Chloritic stripes. Gray veins with sulphide in brown phyllitic phyllite.
LEGEND
OAKDALE QUARTZITE
Dip Degrees
Strike Bearing
Approx. Degrees
JOINTS
Tunnel - S76°28'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 20+00 TO 30+00
20 10 0 20 40 FT.

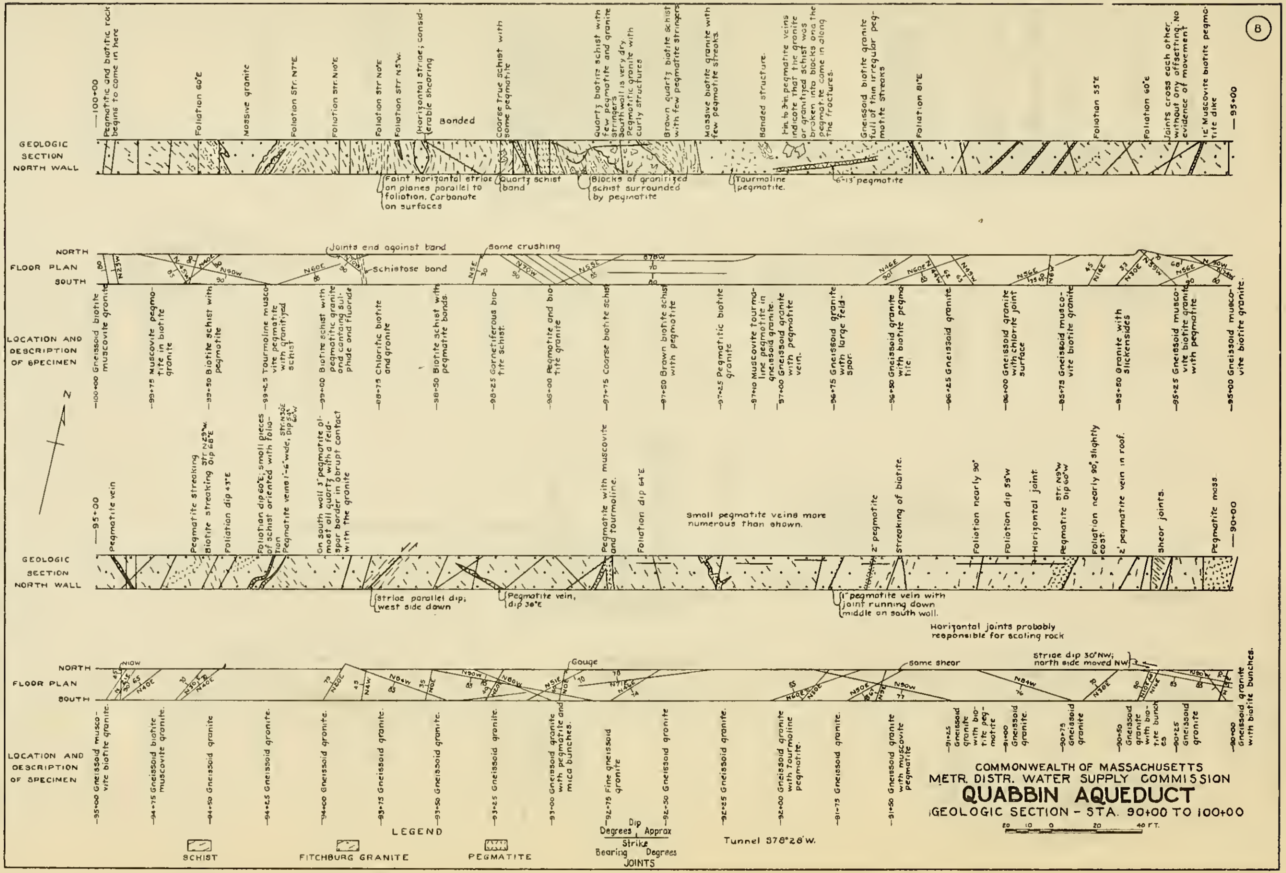

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 30+00 TO 40+00
20 10 0 20 40 FT.
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
CONTACT
BOYLSTON SCHIST — PHYLLITIC QUARTZITE (OAKDALE)
N-W Joints strongest.
N-W Joints more numerous than shown, spaced approx. 10ft. apart.
Slight crag, indicating west side down
Crush
Calcite
Strike N4°W. Dip 80°W
N
LEGEND
BOYLSTON SCHIST
OAKDALE QUARTZITE
Dip Degrees Approx. Strike Bearing Degrees JOINTS
Tunnel - S76°28'W
-40+00 Coarsely micaceous schist.
-39+50 Micaceous schist with quartz lenses and sulphide
-39+00 Band of quartz with lens of coarse micaceous schist
-38+50 Coarsely micaceous quartzose schist.
-38+20 Coarsely micaceous quartzose schist
-38+00 Coarsely micaceous quartzose schist.
-37+50 Quartzose micaceous schist with small quartz streaks
-37+00 Pegmatite and micaceous schist
-36+75 Micaceous quartzose schist with quartz lenses.
-36+50 Crenulate folded micaceous schist with quartz and carbonate streaks.
-36+00 Micaceous quartzose schist with quartz streaks and andalusite crystals.
-35+50 Phyllitic quartzite
-35+00 Phyllitic quartzite
-35+00 Phyllitic quartzite.
-34+50 Quartzite with quartz streaks and carbonate filled fractures.
-34+00 Quartzite with quartz streaks and carbonate filled fractures.
-33+50 Phyllitic quartzite with quartz vein
-33+00 Quartzite and phyllitic quartzite with small quartz streaks and lenses.
-32+50 Phyllitic quartzite with carbonate
-32+00 Phyllitic quartzite with greenish (diopside) bands
-31+50 Phyllitic quartzite
-31+00 Phyllitic quartzite with quartz vein.
-30+50 Phyllitic quartzite with quartz vein.
-30+00 Phyllitic quartzite.
Foliation strike N3W Dip 17W. Small quartz lenses in schist more numerous.
Small quartz lenses with little feldspar.
Quartz lens, 12' long, 3" wide; contains biotite streaks with fine white feldspar associated
The schist is laminated with interbedded quartzose streaks Foliation Str N4E Dip 20W
Linear parallelism N4°W
Coarsely micaceous
Pegmatite with glassy quartz
Coarsely micaceous and similar to andalusitic schist
Beds of more phyllitic quartzite
Somewhat coarser than phyllite. Contains small flakes, possibly ottrelite, parallel to and at right angles with the foliation.
Thin quartz bands. Foliation Str N3°W. Dip 17°W
Phyllitic quartzite type Numerous discontinuous calcite filled veins. Quartz bands.
Discontinuous calcite filled veins; probably tension openings. Foliation Strike N4°W. Dip 18°W.
Blocky
Phyllitic quartzite. Foliation Str N13°W Dip 20°W
Fine grained phyllitic quartzite. A very definite sheeting or bedding joint structure Foliation. Strike N14°W; Dip 24°W.
Fine grained dense phyllitic quartzite
Foliation Str. N16°E Dip 22°W
Considerable quartz and carbonate Much fracturing and shearing. Foliation dip 20°W
Small quartz veins
Foliation dip 40°W Phyllitic quartzite Occurrence of narrow greenish bands possibly containing diopside.
Small fractures and joints contain carbonate.
Shearing parallel to the foliation. Small quartz veins
Foliation Str N14°W. dip 22°W.
Small lenses of quartz pegmatite containing sulphide

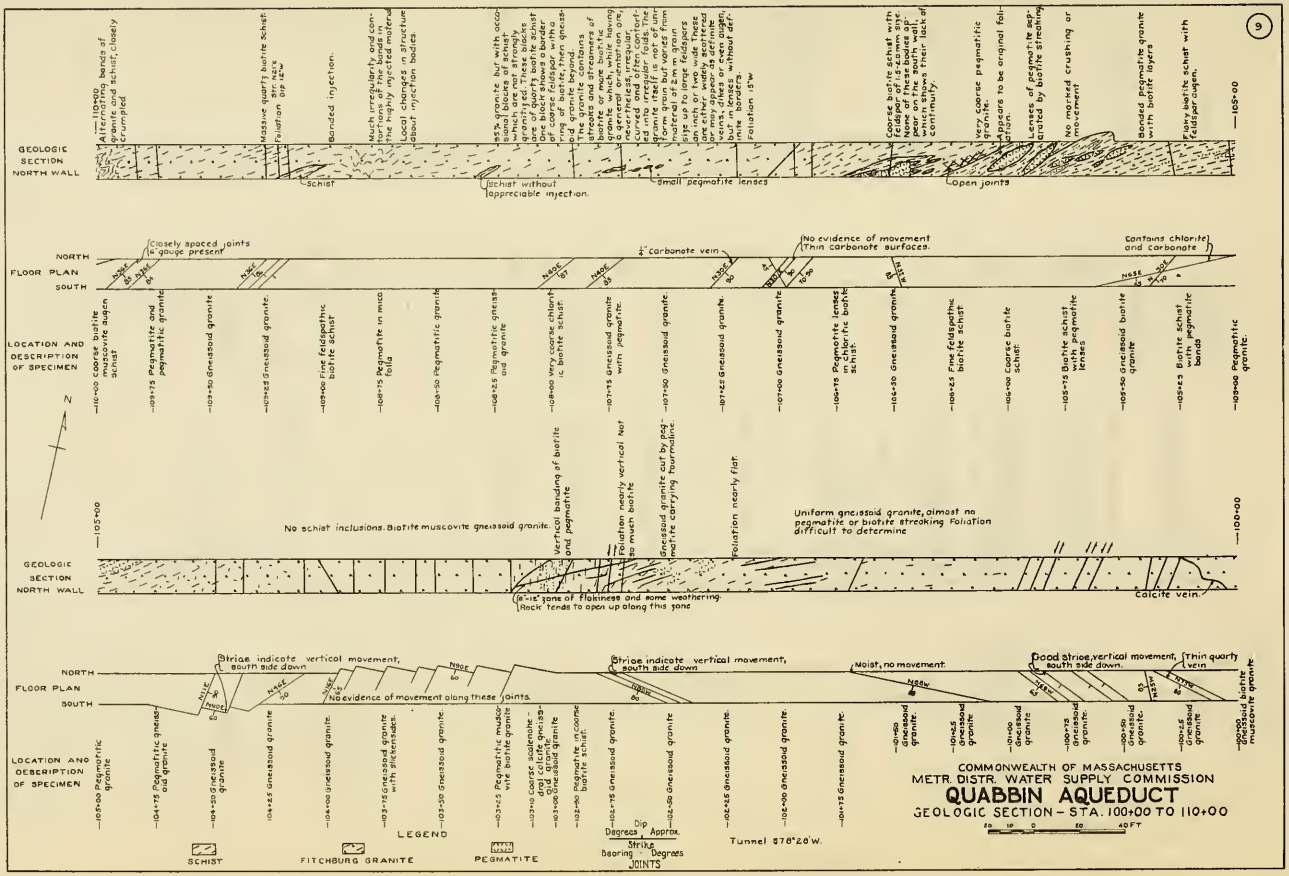

3
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
50+00
Foliation dip 27°W
Quartz lenses and bands more numerous.
Foliation Strike N14°W Dip 28°W
Andalusite crystals 1/2" diameter near pegmatite which contains about 1/2 feldspar
Foliation dip 27°W
Foliation and contact dip 28°W Margin irregular.
2' schist band
Strike of pegmatite N1°E.
Foliation Strike N9°W Dip 27°W
Foliation dip 27°W
Foliation 20°W
Linear parallelism Str N9°E Dip 31°W
Foliation 27°W
Foliation Strike N4°W Dip 45°W
Possible movement; west side down.
45+00
12" Crush
Slight crush
Striae horizontal.
50+00 Quartzose micaceous schist with andalusite and quartz streaks
49+50 Quartzose sericitic schist
49+00 Quartzose sericitic schist
48+50 Granite
48+00 Quartzose micaceous schist with andalusite.
47+50 Quartzite with quartz veins.
47+00 Phyllitic quartzite
46+50 Quartzose micaceous schist.
46+00 Quartzose micaceous sericitic schist
45+50 Quartz pegmatite
45+00 Quartzose micaceous schist with quartz pegmatite.
N
45+00
Quartz lenses with feldspar.
Foliation dip 23°W.
Quartzose layers. Small crenulate folds.
Foliation Strike N10°W Dip 41°W
Linear parallelism N10°W.
Foliation Strike N9°W Dip 43°W
Foliation dip 25°W.
Small pegmatitic quartz veins cut across foliation. Some contain appreciable white feldspar.
Foliation 13°W. Small andalusite knots. Quartzitic and micaceous bands the latter predominating.
Foliation Strike N9°W Dip 40°W
Foliation Strike N2°W Dip 16°W
Foliation Strike N1°E. Dip 32°W.
Quartzose and phyllitic layers quartz veins and streaks.
Linear parallelism N4°W.
Foliation dip 15°W Foliation somewhat crinkled
6-8 quartz vein obscuring normal fault. Considerable crushing. Quartz contains sulphide
Quartz lenses
Quartzite band 12' wide, lenses out
Foliation Strike N12°W Dip 18°W
Dip 5°W.
40+00
Quartz lenses
6' Crush
2' Crush
Much crinkling indication of thrust from the west
Gouge west side down
45+00 Quartzose micaceous schist with quartz pegmatite
44+50 Quartzose micaceous schist with quartz lenses.
44+00 Quartzose micaceous schist with andalusite and sulphide
43+75 Quartz pegmatite with garnet.
43+50 Quartzose sericitic schist.
43+00 Quartzose micaceous sericitic schist with andalusite
42+50 Quartzose micaceous sericitic schist.
42+00 Quartzose micaceous schist with quartz streaks
41+50 Quartzose micaceous schist
41+25 Quartz containing quartz filled cavity
41+00 Micaceous schist with quartz veins
40+50 Micaceous schist with quartzose layer.
40+00 Coarsely micaceous schist
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 40+00 TO 50+00
20 10 0 20 40 FT.
LEGEND
BOYLSTON SCHIST
PEGMATITE
Dip Degrees, Approx.
Strike Bearing Degrees
JOINTS
Tunnel S78°28'W

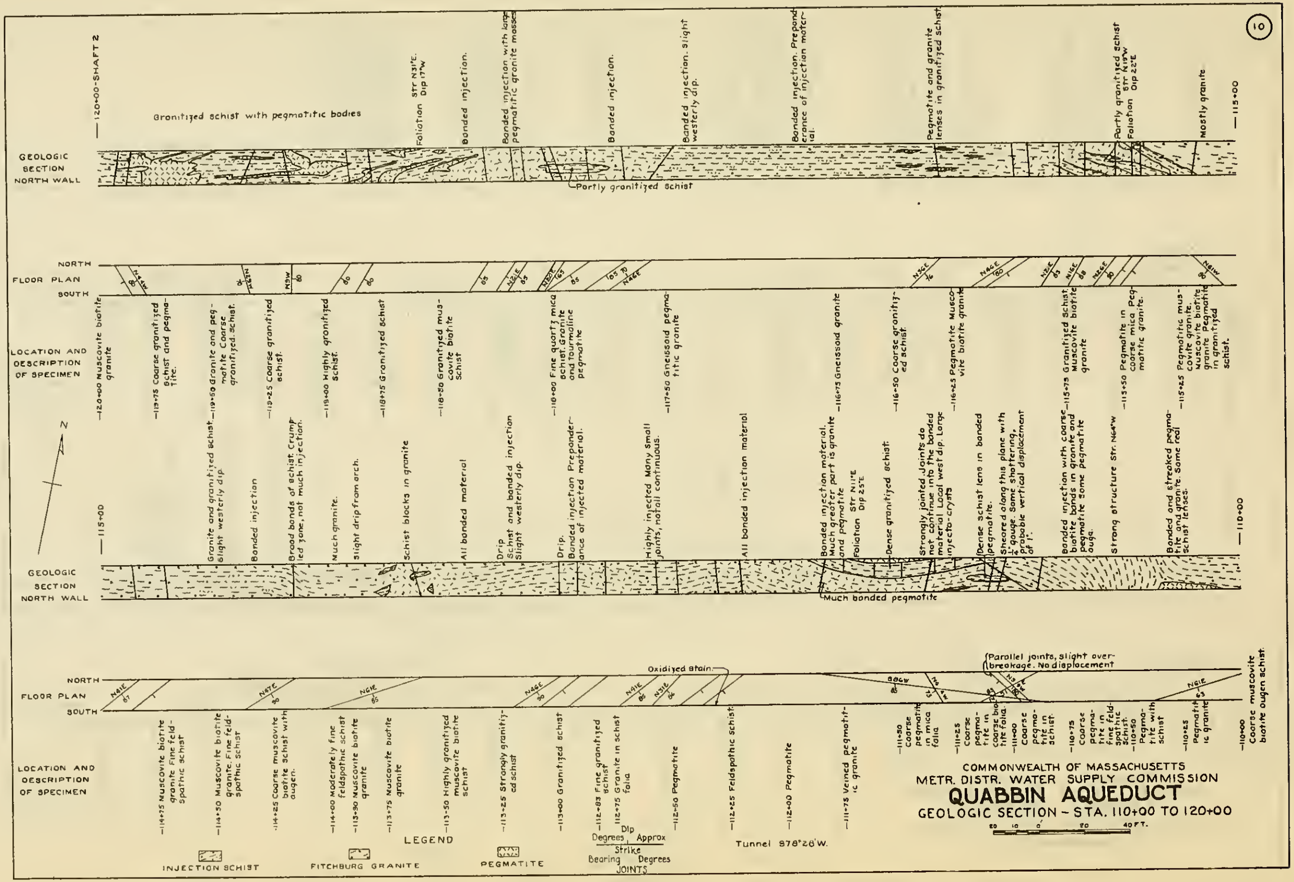

4
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
GEOLOGIC SECTION NORTH WALL
CONTACT
FITCHBURG GRANITE
BOYLSTON SCHIST
LEGEND
FITCHBURG GRANITE
BOYLSTON SCHIST
SCHIST
JOINTS
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 50+00 TO 60+00

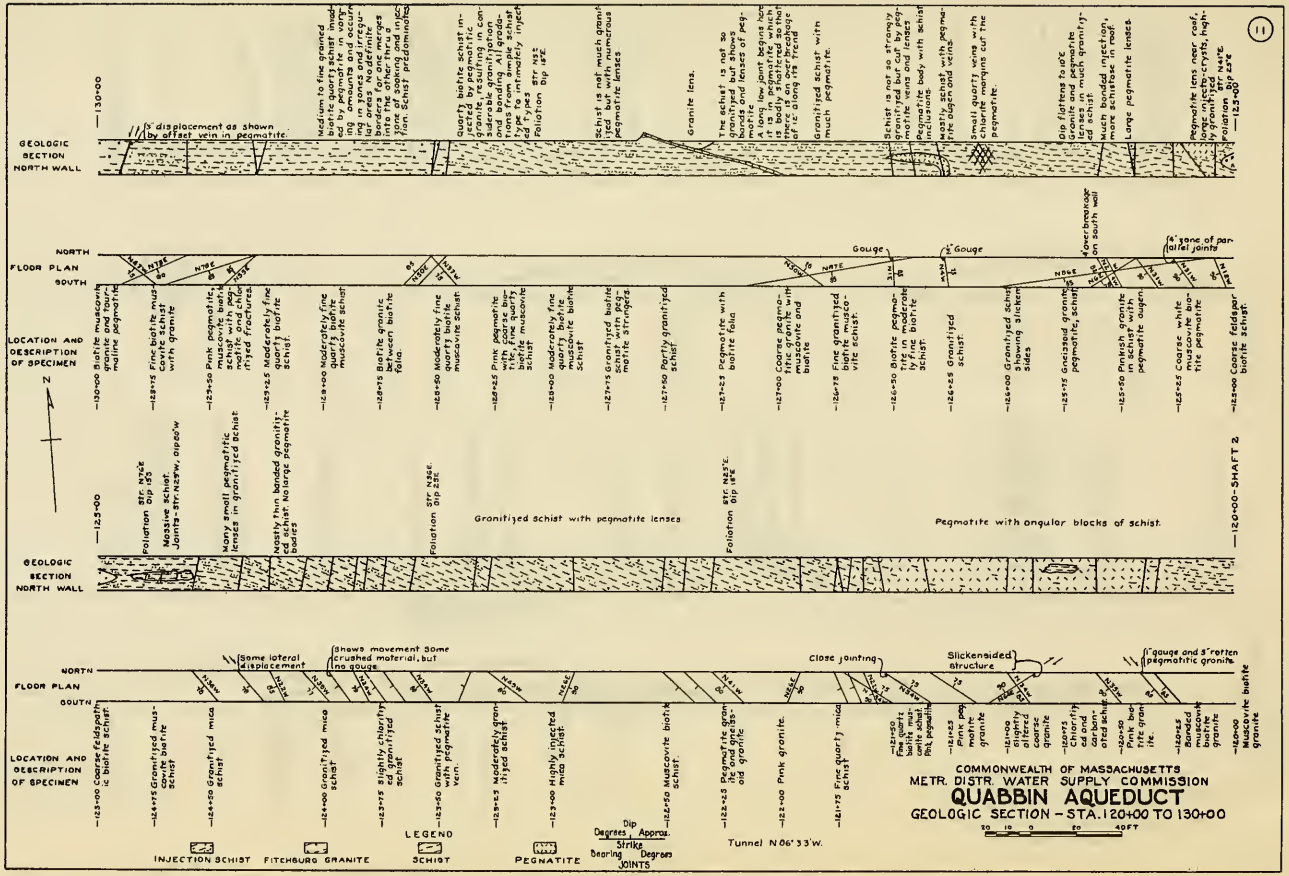

6
GEOLOGIC SECTION NORTH WALL
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
Granite throughout containing lenses of biotite oriented with foliation.
Granite with irregular tourmaline pegmatite.
These joints nearly normal to foliation.
Granite with irregular pegmatite.
Joint normal to foliation.
Foliation preserved in pegmatite
Granite is quite massive.
Contact.
LEGEND
FITCHBURG GRANITE
PEGMATITE
SCHIST
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel 87°28'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 70+00 TO 80+00


7
GEOLOGIC SECTION NORTH WALL
Tendency to flat jointing and scaling in the arch, "popping rock."
Flat arch.
Flat joints are not long and continuous but short and with fresh surfaces.
Pattern of pegmatite veins in roof.
Joint with pegmatite
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
Flat joints.
Some tourmaline, much muscovite, some biotite near margin.
Streaking of biotite and pegmatite.
Horizontal striae.
Horizontal striae, a little gouge on one joint.
Wall fairly smooth, arch normal.
Flat roof, but not much scaling.
Tendency to flat jointing in roof.
Roof has scaled.
LEGEND
FITCHBURG GRANITE
PEGMATITE
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel 57°28'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 80+00 TO 90+00

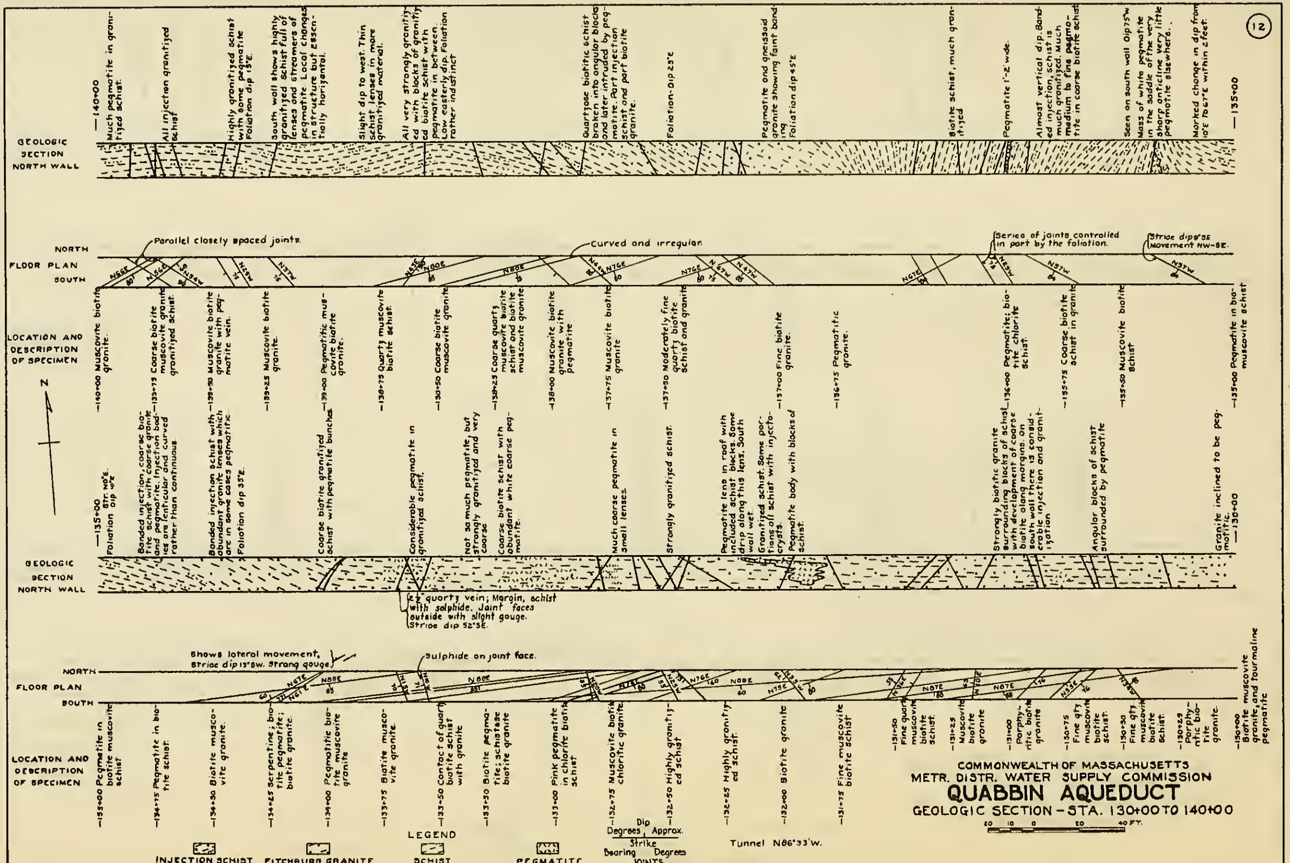

8
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 90+00 TO 100+00
Tunnel S78°28'W.
LEGEND
SCHIST
FITCHBURG GRANITE
PEGMATITE
Dip Degrees Approx
Strike Bearing Degrees
JOINTS


9
GEOLOGIC SECTION NORTH WALL
Alternating bands of granite and schist, closely crumpled
Massive quartz biotite schist. Strike N21°E Foliation dip 15°W
Banded injection.
Much irregularity and contortions of the bands in the highly injected material
Local changes in structure about injection bodies.
85% granite but with occasional blocks of schist which are not strongly granitized. These blocks are of quartz biotite schist. One block shows a border of coarse feldspar with a ring of biotite, then gneissoid granite beyond. The granite contains streaks and streamers of biotite or more biotite granite which, while having a general orientation, are nevertheless irregular, curved and often contorted into irregular folds. The granite itself is not of uniform grain but varies from material of 2 mm grain size up to large feldspars an inch or two wide. These are either widely scattered or may appear as definite veins, lenses or even augen, but in lenses without definite borders.
Foliation 15°W
Coarse biotite schist with feldspar of 1.5-2.0 mm size. None of these bodies appear on the south wall, which shows their lack of continuity.
Very coarse pegmatitic granite.
Appears to be original foliation.
Lenses of pegmatite separated by biotite streaking.
No marked crushing or movement
Banded pegmatite granite with biotite layers
Fairly biotite schist with feldspar augen.
105+00
Schist
Schist without appreciable injection.
Small pegmatite lenses
Open joints
FLOOR PLAN
NORTH
SOUTH
Closely spaced joints 1/4" gouge present
1/4" carbonate vein
No evidence of movement Thin carbonate surfaces.
Contains chlorite and carbonate
LOCATION AND DESCRIPTION OF SPECIMEN
110+00 Coarse biotite muscovite augen schist
109+75 Pegmatite and pegmatitic granite
109+50 Gneissoid granite
109+25 Gneissoid granite.
109+00 Fine feldspathic biotite schist
108+75 Pegmatite in mica folia
108+50 Pegmatitic granite
108+25 Pegmatitic gneissoid granite
108+00 Very coarse chloritic biotite schist.
107+75 Gneissoid granite with pegmatite.
107+50 Gneissoid granite.
107+25 Gneissoid granite.
107+00 Gneissoid granite
106+75 Pegmatite lenses in chloritic biotite schist.
106+50 Gneissoid granite
106+25 Fine feldspathic biotite schist.
106+00 Coarse biotite schist.
105+75 Biotite schist with pegmatite lenses
105+50 Gneissoid biotite granite
105+25 Biotite schist with pegmatite bands
105+00 Pegmatitic granite.
N
105+00
No schist inclusions. Biotite muscovite gneissoid granite.
Vertical banding of biotite and pegmatite
Foliation nearly vertical Not so much biotite
Gneissoid granite cut by pegmatite carrying tourmaline.
Foliation nearly flat.
Uniform gneissoid granite, almost no pegmatite or biotite streaking Foliation difficult to determine
100+00
GEOLOGIC SECTION NORTH WALL
1/8"-1/2" zone of flakiness and some weathering. Rock tends to open up along this zone
Calcite vein.
FLOOR PLAN
NORTH
SOUTH
Striae indicate vertical movement, south side down
No evidence of movement along these joints.
Striae indicate vertical movement, south side down
Moist, no movement.
Good striae, vertical movement, south side down.
Thin quartz vein
LOCATION AND DESCRIPTION OF SPECIMEN
105+00 Pegmatitic granite
104+75 Pegmatitic gneissoid granite
104+50 Gneissoid granite
104+25 Gneissoid granite
104+00 Gneissoid granite.
103+75 Gneissoid granite with slickensides.
103+50 Gneissoid granite.
103+25 Pegmatitic muscovite biotite granite
103+00 Coarse scalenohedral calcite gneissoid granite
103+00 Gneissoid granite
102+50 Pegmatite in coarse biotite schist.
102+75 Gneissoid granite.
102+50 Gneissoid granite
102+25 Gneissoid granite.
102+00 Gneissoid granite.
101+75 Gneissoid granite.
101+50 Gneissoid granite.
101+25 Gneissoid granite
101+00 Gneissoid granite
100+75 Gneissoid granite.
100+50 Gneissoid granite.
100+25 Gneissoid granite
100+00 Gneissoid biotite muscovite granite.
LEGEND
SCHIST
FITCHBURG GRANITE
PEGMATITE
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel S78°28'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 100+00 TO 110+00
20 10 0 20 40 FT

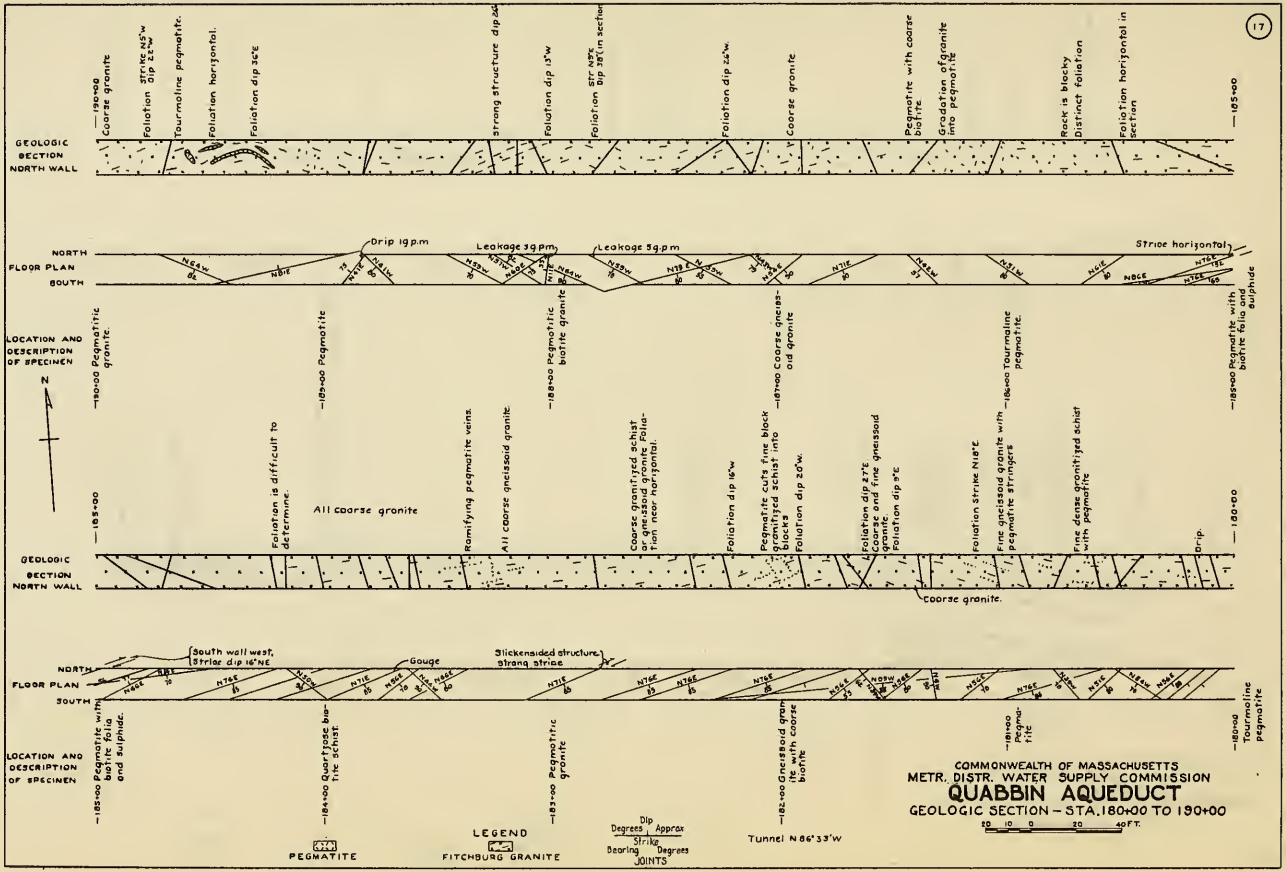

10
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 110+00 TO 120+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
120+00-SHAFT 2
115+00
110+00
Granitized schist with pegmatitic bodies
Foliation Str N31°E. Dip 17°W
Banded injection.
Banded injection with large pegmatitic granite masses
Partly granitized schist
Banded injection. Slight westerly dip.
Banded injection. Preponderance of injection material.
Pegmatite and granite lenses in granitized schist
Partly granitized schist Foliation Str N15°W Dip 22°E
Mostly granite
120+00 Muscovite biotite granite
119+75 Coarse granitized schist and pegmatite.
119+50 Granite and pegmatite Coarse granitized schist.
119+25 Coarse granitized schist.
119+00 Highly granitized schist.
118+75 Granitized schist
118+50 Granitized muscovite biotite schist
118+00 Fine quartz mica schist. Granite and tourmaline pegmatite
117+50 Gneissoid pegmatitic granite
116+75 Gneissoid granite
116+50 Coarse granitized schist.
116+25 Pegmatite muscovite biotite granite
115+75 Granitized schist. Muscovite biotite granite
115+50 Pegmatite in coarse mica pegmatitic granite.
115+25 Pegmatitic muscovite granite. Muscovite biotite granite Pegmatite in granitized schist.
Granite and granitized schist. Slight westerly dip.
Banded injection
Broad bands of schist. Crumpled zone, not much injection.
Much granite.
Slight drip from arch.
Schist blocks in granite
All banded material
Drip. Schist and banded injection Slight westerly dip.
Drip. Banded injection Preponderance of injected material.
Highly injected. Many small joints, not all continuous.
All banded injection material
Bonded injection material. Much greater part is granite and pegmatite
Foliation Str N11°E Dip 25°E
Dense granitized schist.
Strongly jointed. Joints do not continue into the banded material. Local west dip. Large injecto-crysts
Dense schist lens in banded pegmatite.
Sheared along this plane with ¼" gouge. Some shattering, probable vertical displacement of 1".
Banded injection with coarse biotite bands in granite and pegmatite some pegmatite auga.
Strong structure Str. N64°W
Banded and streaked pegmatite and granite. Some real schist lenses.
Much banded pegmatite
Parallel joints, slight overbreakage. No displacement
Oxidized stain
114+75 Muscovite biotite granite Fine feldspathic schist
114+50 Muscovite biotite granite. Fine feldspathic schist
114+25 Coarse muscovite biotite schist with augen.
114+00 Moderately fine feldspathic schist
113+90 Muscovite biotite granite
113+75 Muscovite biotite granite
113+50 Highly granitized muscovite biotite schist
113+25 Strongly granitized schist
113+00 Granitized schist
112+83 Fine granitized schist
112+75 Granite in schist folia
112+50 Pegmatite
112+25 Feldspathic schist
112+00 Pegmatite
111+75 Veined pegmatitic granite
111+50 Coarse pegmatite in mica folia
111+25 Coarse pegmatite in coarse biotite folia.
111+00 Coarse pegmatite in schist
110+75 Coarse pegmatite in fine feldspathic schist.
110+50 Pegmatite with schist
110+25 Pegmatitic granite
110+00 Coarse muscovite biotite augen schist.
LEGEND
INJECTION SCHIST
FITCHBURG GRANITE
PEGMATITE
Dip Degrees Approx
Strike Bearing Degrees
JOINTS
Tunnel S78°28'W.
N

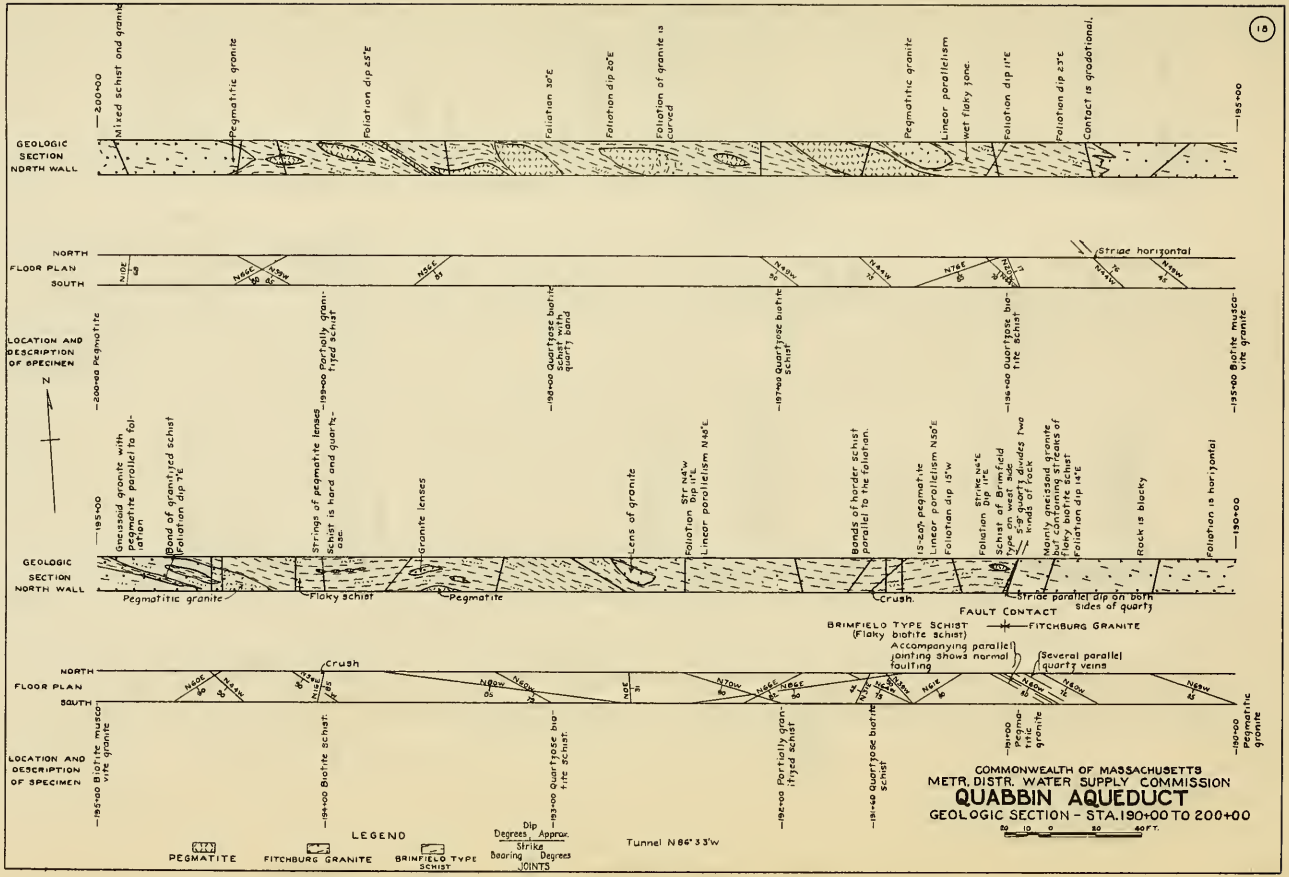


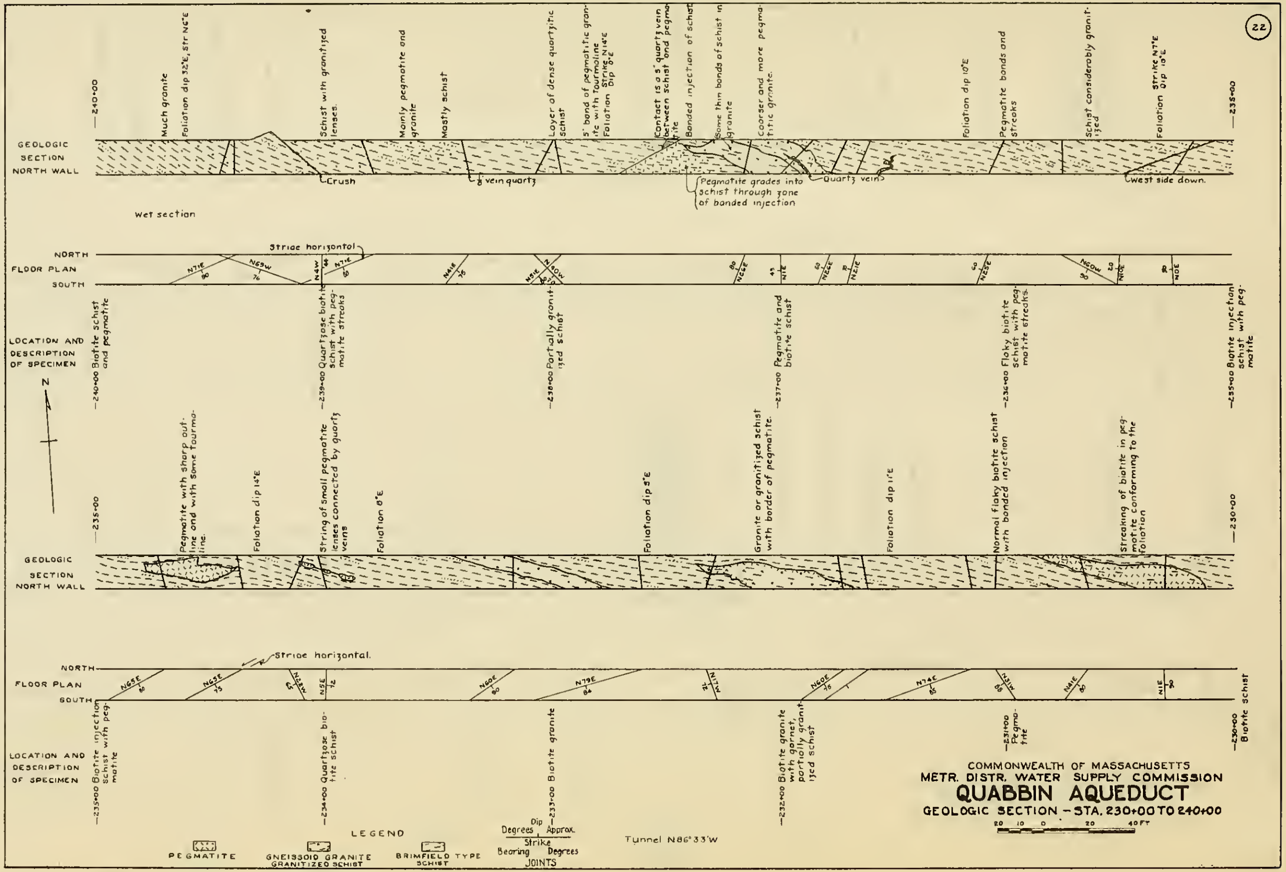
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
—130+00
—125+00
—120+00-SHAFT 2
—125+00
—120+00
5" displacement as shown by offset vein in pegmatite.
Medium to fine grained biotite quartz schist invaded by pegmatite in varying amounts and occurring in zones and irregular areas. No definite borders for one merges into the other thru a zone of soaking and injection. Schist predominates.
Quartz biotite schist injected by pegmatitic granite, resulting in considerable granitization and banding. All gradations from simple schist type to intimately injected types.
Foliation Str N5°E Dip 15°E
Schist is not much granitized but with numerous pegmatite lenses.
Granite lens.
The schist is not so granitized but shows bands and lenses of pegmatite.
A long low joint begins here it is in pegmatite which is badly shattered so that there is an overbreakage of 12" along its trend.
Granitized schist with much pegmatite.
Schist is not so strongly granitized but cut by pegmatite veins and lenses.
Pegmatite body with schist inclusions.
Mostly schist with pegmatite augen and veins.
Small quartz veins with chlorite margins cut the pegmatite.
Dip flattens to 10°E. Granite and pegmatite lenses in much granitized schist.
Much banded injection, more schistose in roof.
Large pegmatite lenses.
Pegmatite lens near roof, large injecto-crysts, highly granitized.
Foliation Str N41°E Dip 23°E
—125+00
Gouge
½" Gouge
4" overbreakage on south wall
4" zone of parallel joints
—130+00 Biotite muscovite granite and tourmaline pegmatite
—129+75 Fine biotite muscovite schist with granite
—129+50 Pink pegmatite, muscovite biotite schist with pegmatite and chloritized fractures.
—129+25 Moderately fine quartz biotite schist.
—129+00 Moderately fine quartz biotite muscovite schist
—128+75 Biotite granite between biotite folia.
—128+50 Moderately fine quartz biotite muscovite schist.
—128+25 Pink pegmatite with coarse biotite, fine quartz biotite muscovite schist
—128+00 Moderately fine quartz biotite muscovite biotite schist
—127+75 Granitized biotite schist with pegmatite stringers.
—127+50 Partly granitized schist
—127+25 Pegmatite with biotite folia
—127+00 Coarse pegmatitic granite with muscovite and biotite
—126+75 Fine granitized biotite muscovite schist.
—126+50 Biotite pegmatite in moderately fine biotite schist.
—126+25 Granitized schist.
—126+00 Granitized schist showing slickensides
—125+75 Gneissoid granite, pegmatite, schist
—125+50 Pinkish granite in schist with pegmatite augen.
—125+25 Coarse white muscovite biotite pegmatite
—125+00 Coarse feldspar biotite schist.
Foliation Str. N76°E Dip 15°S
Massive schist. Joints-Str. N25°W, Dip 80°W
Many small pegmatitic lenses in granitized schist.
Nastly thin banded granitized schist. No large pegmatite bodies
Foliation Str N36°E Dip 25°E
Granitized schist with pegmatite lenses
Foliation Str. N25°E Dip 18°E
Pegmatite with angular blocks of schist.
Some lateral displacement
Shows movement some crushed material, but no gouge
Close jointing
Slickensided structure
1" gouge and 5" rotten pegmatitic granite
—123+00 Coarse feldspathic biotite schist.
—124+75 Granitized muscovite biotite schist
—124+50 Granitized mica schist
—124+00 Granitized mica schist
—123+75 Slightly chloritized granitized schist
—123+50 Granitized schist with pegmatite vein.
—123+25 Moderately granitized schist
—123+00 Highly injected mica schist.
—122+50 Muscovite biotite schist.
—122+25 Pegmatite granite and gneissoid granite
—122+00 Pink granite.
—121+75 Fine quartz-mica schist
—121+50 Fine quartz biotite muscovite schist. Pink pegmatite
—121+25 Pink pegmatite granite
—121+00 Slightly altered coarse granite
—120+75 Chloritized and carbonated schist
—120+50 Pink biotite granite.
—120+25 Banded muscovite biotite granite
—120+00 Muscovite biotite granite
LEGEND
INJECTION SCHIST
FITCHBURG GRANITE
SCHIST
PEGMATITE
Dip Degrees, Approx.
Strike Bearing Degrees
JOINTS
Tunnel N 06° 33' W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 120+00 TO 130+00
20 10 0 20 40 FT



COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 130+00 TO 140+00
12
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
LEGEND
INJECTION SCHIST
FITCHBURG GRANITE
SCHIST
PEGMATITE
JOINTS
Dip Degrees, Approx.
Strike Bearing Degrees
Tunnel N86°33'W.
Parallel closely spaced joints.
Curved and irregular.
Series of joints controlled in part by the foliation.
Sulphide on joint face.
Shows lateral movement, Striae dip 15°SW. Strong gouge.
Granite inclined to be pegmatitic.
Angular blocks of schist surrounded by pegmatite
Strongly granitized schist.
Much coarse pegmatite in small lenses.
Considerable pegmatite in granitized schist.
Coarse biotite granitized schist with pegmatite bunches
Foliation dip 35°E.
Biotite schist, much granitized
Pegmatite 1'-2' wide.
Foliation dip 23°E
Slight dip to west. Thin schist lenses in more granitized material.
All injection granitized schist
Much pegmatite in granitized schist.


17
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 180+00 TO 190+00
20 10 0 20 40 FT.
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
190+00 Coarse granite
Foliation strike N5°W dip 22°W
Tourmaline pegmatite.
Foliation horizontal.
Foliation dip 32°E
strong structure dip 56°
Foliation dip 13°W
Foliation strike N8°E dip 38° in section
Foliation dip 22°W.
Coarse granite
Pegmatite with coarse biotite
Gradation of granite into pegmatite
Rock is blocky Distinct foliation
Foliation horizontal in section
185+00
Drip 19 g.p.m.
Leakage 39 g.p.m.
Leakage 5 g.p.m.
Strike horizontal
180+00 Pegmatitic granite.
185+00 Pegmatite
181+00 Pegmatitic biotite granite
187+00 Coarse gneissoid granite
186+00 Tourmaline pegmatite.
185+00 Pegmatite with biotite folia and sulphide
Foliation is difficult to determine.
All coarse granite
Ramifying pegmatite veins.
All coarse gneissoid granite.
Coarse granitized schist or gneissoid granite. Foliation near horizontal.
Foliation dip 16°W
Pegmatite cuts fine black granitized schist into blocks
Foliation dip 20°W.
Foliation dip 27°E
Coarse and fine gneissoid granite.
Foliation dip 5°E.
Foliation strike N18°E.
Fine gneissoid granite with pegmatite stringers
Fine dense granitized schist with pegmatite
Drip.
Coarse granite.
South wall west, Striae dip 16° NE
Gouge
Slickensided structure, strong striae
185+00 Pegmatite with biotite folia and sulphide.
184+00 Quartzose biotite schist.
183+00 Pegmatitic granite
182+00 Gneissoid granite with coarse biotite.
181+00 Pegmatite
180+00 Tourmaline pegmatite
Tunnel N 86° 33' W
LEGEND
PEGMATITE
FITCHBURG GRANITE
Dip
Degrees
Approx
Strike
Bearing
Degrees
JOINTS


18
GEOLOGIC SECTION NORTH WALL
200+00
Mixed schist and granite
Pegmatitic granite
Foliation dip 25°E
Foliation 30°E
Foliation dip 20°E
Foliation of granite is curved
Pegmatitic granite
Linear parallelism
wet flaky zone.
Foliation dip 11°E
Foliation dip 23°E
Contact is gradational.
195+00
NORTH
FLOOR PLAN
SOUTH
Striae horizontal
LOCATION AND DESCRIPTION OF SPECIMEN
N
200+00 Pegmatite
195+00
Gneissoid granite with pegmatite parallel to foliation
Band of granitized schist
Foliation dip 7°E
199+00 Partially granitized schist
Strings of pegmatite lenses
Schist is hard and quartzose.
Granite lenses
198+00 Quartzose biotite schist with quartz band
Lens of granite
Foliation Str N4°W Dip 11°E
Linear parallelism N48°E
197+00 Quartzose biotite schist
Bands of harder schist parallel to the foliation.
15-20% pegmatite
Linear parallelism N50°E
Foliation dip 15°W
196+00 Quartzose biotite schist
Foliation Strike N4°E Dip 11°E
Schist of Brimfield type on west side
5-8% quartz divides two kinds of rock
Mainly gneissoid granite but containing streaks of flaky biotite schist
Foliation dip 14°E
Rock is blocky
Foliation is horizontal
195+00 Biotite muscovite granite
190+00
GEOLOGIC SECTION NORTH WALL
Pegmatitic granite
Flaky schist
Pegmatite
Crush.
Striae parallel dip on both sides of quartz
FAULT CONTACT
BRIMFIELD TYPE SCHIST (Flaky biotite schist)
FITCHBURG GRANITE
Accompanying parallel jointing shows normal faulting
Several parallel quartz veins
NORTH
FLOOR PLAN
SOUTH
Crush
LOCATION AND DESCRIPTION OF SPECIMEN
195+00 Biotite muscovite granite
194+00 Biotite schist.
193+00 Quartzose biotite schist.
192+00 Partially granitized schist
191+40 Quartzose biotite schist
191+00 Pegmatitic granite
190+00 Pegmatitic granite
LEGEND
PEGMATITE
FITCHBURG GRANITE
BRIMFIELD TYPE SCHIST
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel N 86° 33' W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 190+00 TO 200+00
50 10 0 20 40 FT.



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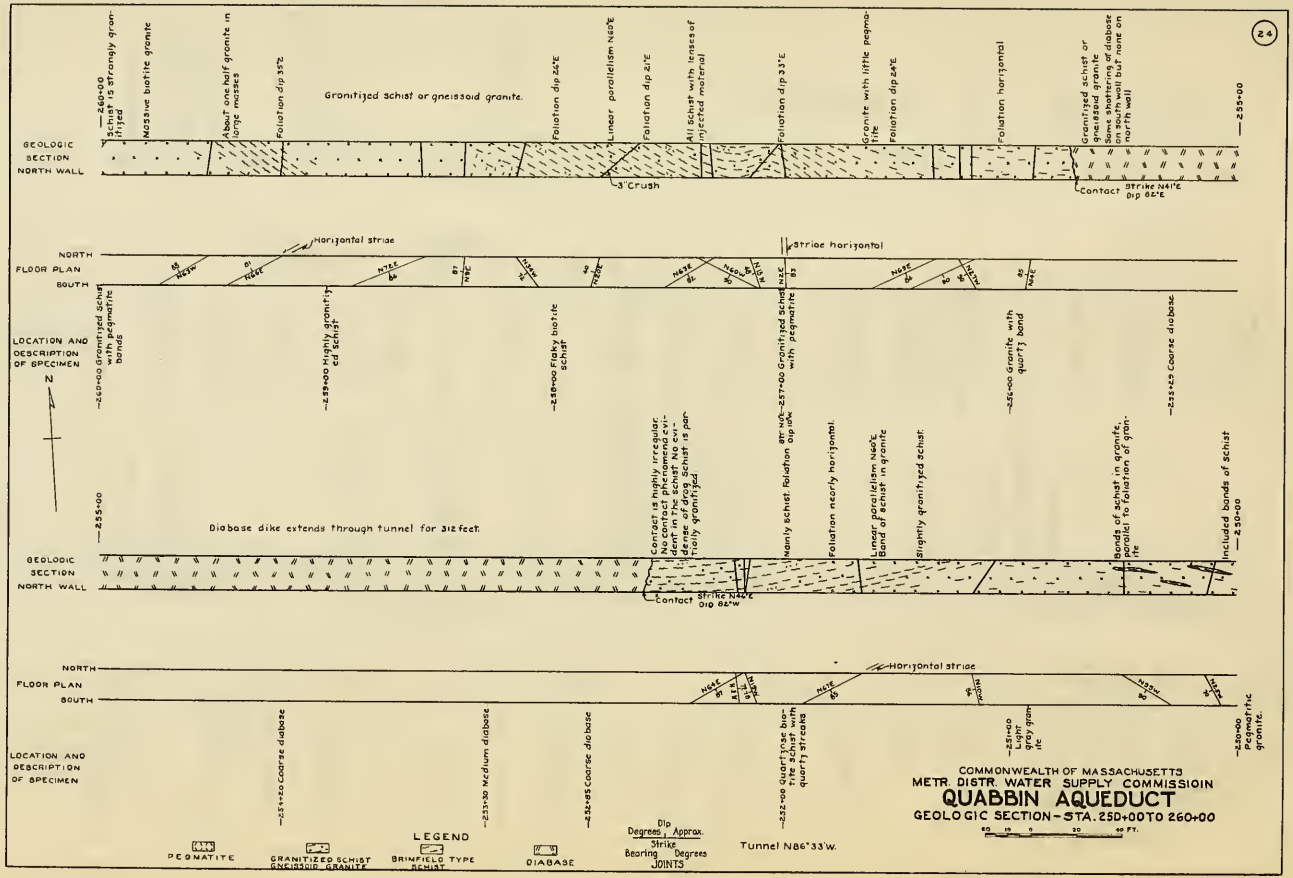
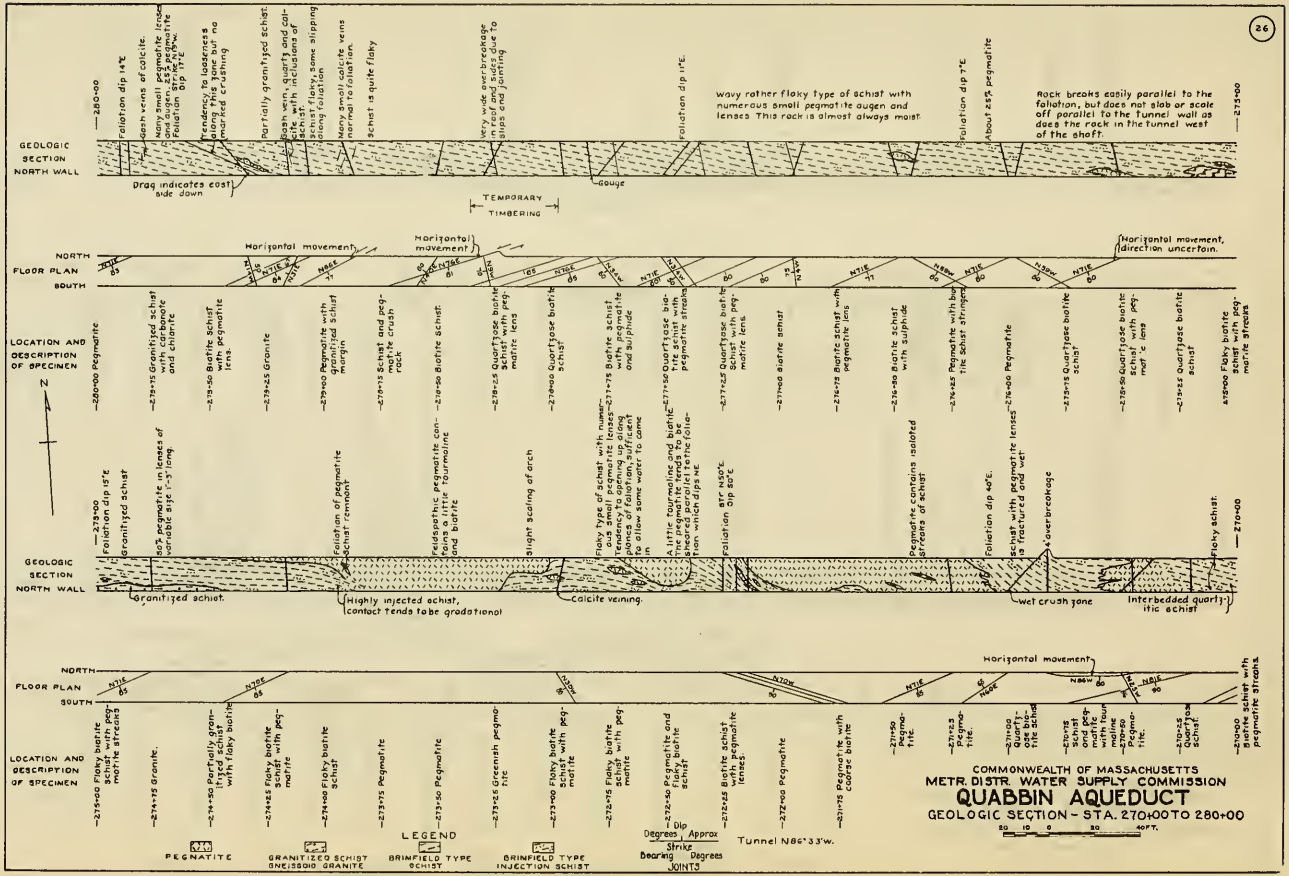
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 230+00 TO 240+00
20 10 0 20 40 FT
Tunnel N86°33'W
LEGEND
PEGMATITE
GNEISSOID GRANITE
GRANITIZED SCHIST
BRIMFIELD TYPE
SCHIST
Dip
Degrees Approx.
Strike
Bearing Degrees
JOINTS
GEOLOGIC SECTION NORTH WALL
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
240+00
235+00
230+00
Much granite
Foliation dip 32°E, str N6°E
Schist with granitized lenses.
Mainly pegmatite and granite
Mostly schist
Layer of dense quartzitic schist
5' band of pegmatitic granite with tourmaline
Foliation Strike N14°E Dip 6°E
Contact is a 5' quartz vein between schist and pegmatite
Banded injection of schist
Some thin bands of schist in granite
Coarser and more pegmatitic granite.
Foliation dip 10°E
Pegmatite bands and streaks
Schist considerably granitized
Foliation Strike N7°E Dip 10°E
Crush
⅛ vein quartz
Pegmatite grades into schist through zone of banded injection
Quartz veins
West side down.
Wet section
Striae horizontal
240+00 Biotite schist and pegmatite
239+00 Quartzose biotite schist with pegmatite streaks
238+00 Partially granitized schist
237+00 Pegmatite and biotite schist
236+00 Flaky biotite schist with pegmatite streaks.
235+00 Biotite injection schist with pegmatite
Pegmatite with sharp outline and with some tourmaline.
Foliation dip 14°E
String of small pegmatite lenses connected by quartz veins
Foliation 8°E
Foliation dip 5°E
Granite or granitized schist with border of pegmatite.
Foliation dip 11°E
Normal flaky biotite schist with banded injection
Streaking of biotite in pegmatite conforming to the foliation
Striae horizontal.
235+00 Biotite injection schist with pegmatite
234+00 Quartzose biotite schist
233+00 Biotite granite
232+00 Biotite granite with garnet, partially granitized schist
231+00 Pegmatite
230+00 Biotite schist


24
GEOLOGIC SECTION NORTH WALL
—260+00 Schist is strongly granitized
Massive biotite granite
About one half granite in large masses
Foliation dip 35°E
Granitized schist or gneissoid granite.
Foliation dip 24°E
Linear parallelism N60°E
Foliation dip 21°E
All schist with lenses of injected material
Foliation dip 33°E
Granite with little pegmatite
Foliation dip 24°E
Foliation horizontal
Granitized schist or gneissoid granite
Some shattering of diabase on south wall but none on north wall
—255+00
3" Crush
Contact Strike N41°E Dip 82°E
NORTH
FLOOR PLAN
SOUTH
Horizontal striae
Striae horizontal
LOCATION AND DESCRIPTION OF SPECIMEN
N
—260+00 Granitized schist with pegmatite bands
—259+00 Highly granitized schist
—258+00 Flaky biotite schist
—257+00 Granitized schist with pegmatite
—256+00 Granite with quartz band
—255+25 Coarse diabase
—255+00
Diabase dike extends through tunnel for 312 feet.
Contact is highly irregular. No contact phenomena evident in the schist. No evidence of drag. Schist is partially granitized.
Mainly schist. Foliation dip 10°W
Foliation nearly horizontal.
Linear parallelism N60°E Band of schist in granite
Slightly granitized schist.
Bands of schist in granite, parallel to foliation of granite
Included bands of schist
—250+00
GEOLOGIC SECTION NORTH WALL
Contact Strike N44°E Dip 82°W
NORTH
FLOOR PLAN
SOUTH
Horizontal striae
LOCATION AND DESCRIPTION OF SPECIMEN
—254+20 Coarse diabase
—253+30 Medium diabase
—252+85 Coarse diabase
—252+00 Quartzose biotite schist with quartz streaks
—251+00 Light gray granite
—250+00 Pegmatitic granite.
LEGEND
PEGMATITE
GRANITIZED SCHIST GNEISSOID GRANITE
BRINFIELD TYPE SCHIST
DIABASE
Dip Degrees, Approx.
Strike Bearing Degrees
JOINTS
Tunnel N86°33'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSIOIN
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 250+00 TO 260+00
FT.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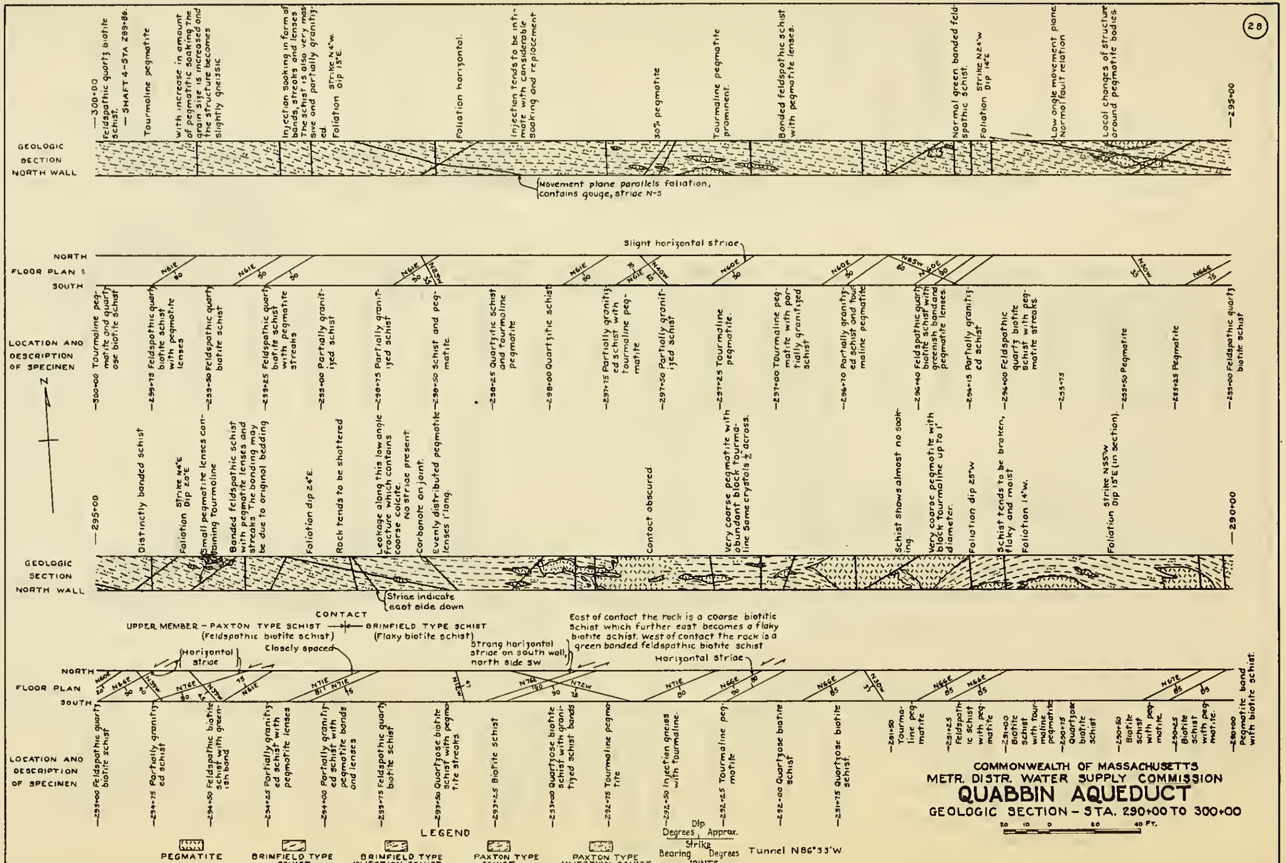
GEOLOGIC SECTION NORTH WALL
Drag indicates east side down
TEMPORARY TIMBERING
Gouge
Wavy rather flaky type of schist with numerous small pegmatite augen and lenses This rock is almost always moist.
Rock breaks easily parallel to the foliation, but does not slab or scale off parallel to the tunnel wall as does the rock in the tunnel west of the shaft.
Horizontal movement
Horizontal movement, direction uncertain.
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
Granitized schist.
Highly injected schist, contact tends to be gradational
Calcite veining.
Wet crush zone
Interbedded quartzitic schist
Flaky schist.
Horizontal movement
LEGEND
PEGMATITE
GRANITIZED SCHIST GNEISSOID GRANITE
BRIMFIELD TYPE SCHIST
BRIMFIELD TYPE INJECTION SCHIST
Dip Degrees, Approx Strike Bearing Degrees JOINTS
Tunnel N86°33'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 270+00 TO 280+00
20 10 0 20 40 FT.



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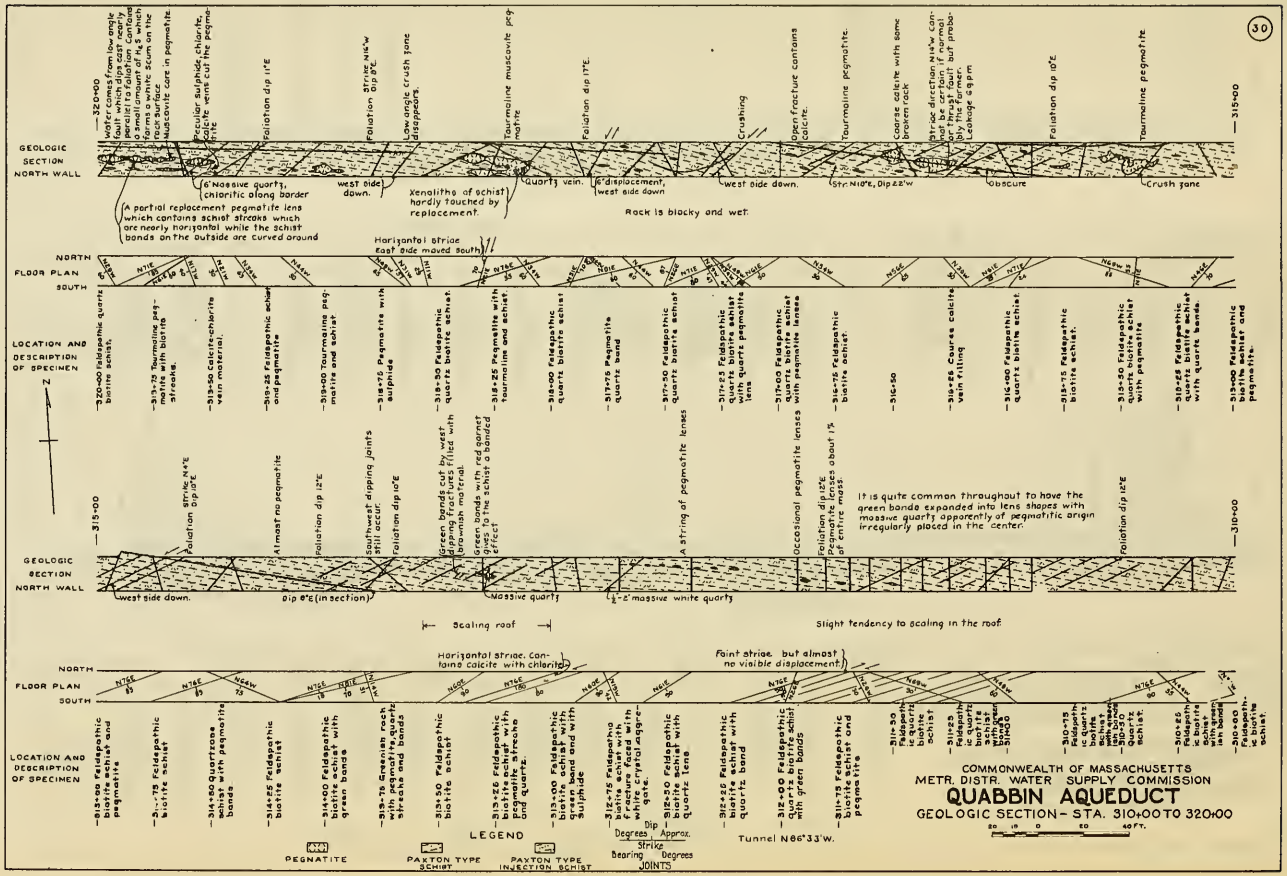
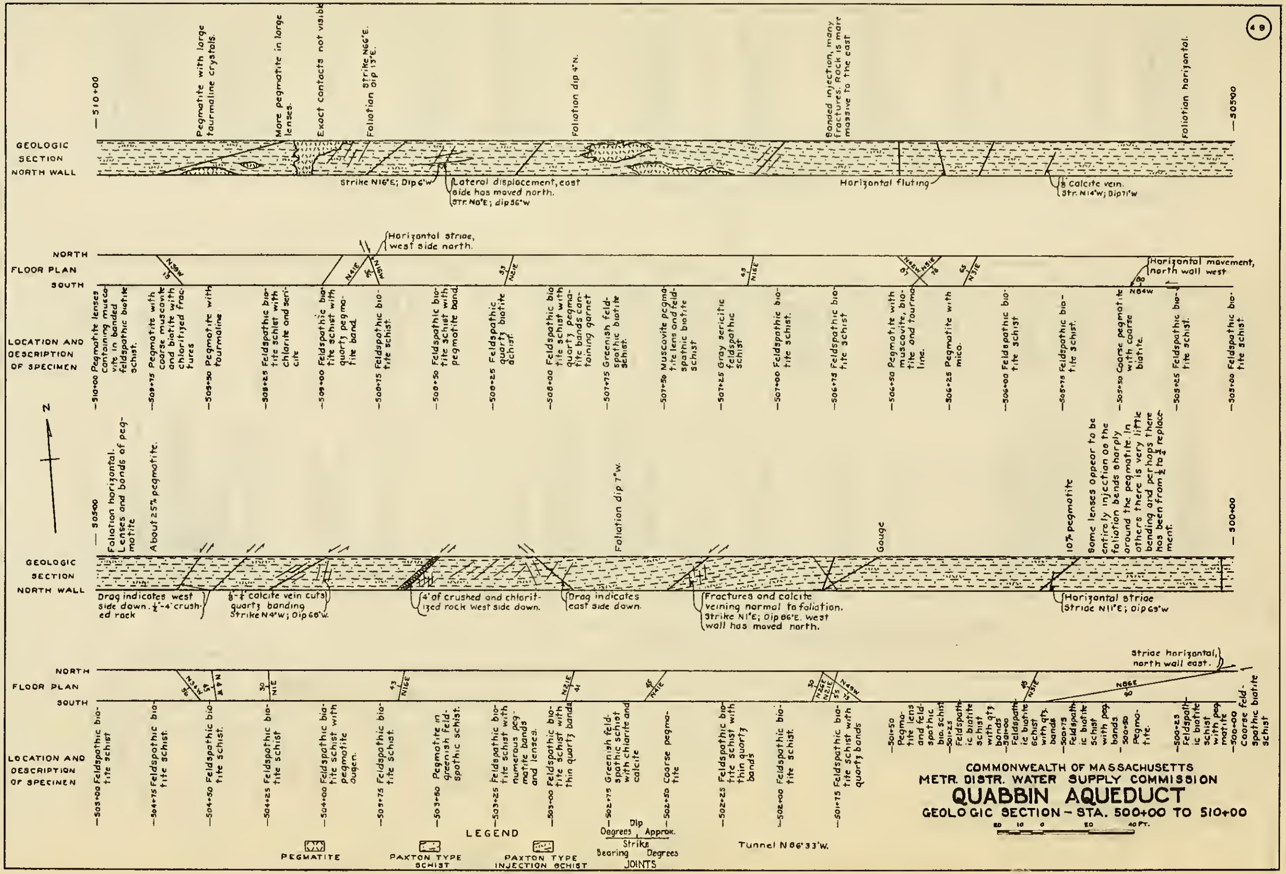
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 290+00 TO 300+00
20 10 0 20 40 FT.
LEGEND
PEGMATITE
BRIMFIELD TYPE SCHIST
BRIMFIELD TYPE INJECTION SCHIST
PAXTON TYPE SCHIST
PAXTON TYPE INJECTION SCHIST
Dip Degrees
Approx. Strike Bearing Degrees
JOINTS
Tunnel N86°33'W
GEOLOGIC SECTION NORTH WALL
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
—300+00
Feldspathic quartz biotite schist.
— SHAFT 4–STA 299+86.
Tourmaline pegmatite
With increase in amount of pegmatitic soaking the grain size is increased and the structure becomes slightly gneissic
Injection soaking in form of bands, streaks and lenses. The schist is also very massive and partially granitized.
Foliation strike N4°W. dip 15°E.
Foliation horizontal.
Injection tends to be intimate with considerable soaking and replacement
Movement plane parallels foliation, contains gouge, striae N-5
30% pegmatite
Tourmaline pegmatite prominent.
Banded feldspathic schist with pegmatite lenses.
Normal green banded feldspathic schist.
Foliation strike N24°W dip 14°E
Low angle movement plane. Normal fault relation
Local changes of structure around pegmatite bodies.
—295+00
Slight horizontal striae
—300+00 Tourmaline pegmatite and quartzose biotite schist
—299+75 Feldspathic quartz biotite schist with pegmatite lenses
—299+50 Feldspathic quartz biotite schist
—299+25 Feldspathic quartz biotite schist with pegmatite streaks
—299+00 Partially granitized schist
—298+75 Partially granitized schist
—298+50 Schist and pegmatite.
—298+25 Quartzitic schist and tourmaline pegmatite
—298+00 Quartzitic schist
—297+75 Partially granitized schist with tourmaline pegmatite
—297+50 Partially granitized schist
—297+25 Tourmaline pegmatite.
—297+00 Tourmaline pegmatite with partially granitized schist
—296+70 Partially granitized schist and tourmaline pegmatite
—296+40 Feldspathic quartz biotite schist with greenish band and pegmatite lenses.
—296+15 Partially granitized schist
—296+00 Feldspathic quartz biotite schist with pegmatite streaks.
—295+75
—295+50 Pegmatite
—295+25 Pegmatite
—295+00 Feldspathic quartz biotite schist
— 295+00
Distinctly banded schist
Foliation strike N4°E dip 20°E
Small pegmatite lenses containing Tourmaline
Banded feldspathic schist with pegmatite lenses and streaks. The banding may be due to original bedding
Foliation dip 24°E.
Rock tends to be shattered
Leakage along this low angle fracture which contains coarse calcite. No striae present
Carbonate on joint.
Evenly distributed pegmatite lenses 1' long.
Contact obscured
Very coarse pegmatite with abundant block tourmaline. Some crystals 1/2" across.
Schist shows almost no soaking
Very coarse pegmatite with block tourmaline up to 1" diameter.
Foliation dip 25°W
Schist tends to be broken, flaky and moist
Foliation 14°W.
Foliation strike N55°W dip 15°E (in section).
— 290+00
Striae indicate east side down
CONTACT
UPPER MEMBER – PAXTON TYPE SCHIST (Feldspathic biotite schist)
BRIMFIELD TYPE SCHIST (Flaky biotite schist)
Horizontal striae
Closely spaced
Strong horizontal striae on south wall, north side SW
East of contact the rock is a coarse biotitic schist which further east becomes a flaky biotite schist. West of contact the rock is a green banded feldspathic biotite schist
Horizontal striae
—295+00 Feldspathic quartz biotite schist
—294+75 Partially granitized schist
—294+50 Feldspathic biotite schist with greenish band
—294+25 Partially granitized schist with pegmatite lenses
—294+00 Partially granitized schist with pegmatite bands and lenses
—293+75 Feldspathic quartz biotite schist
—293+50 Quartzose biotite schist with pegmatite streaks.
—293+25 Biotite schist
—293+00 Quartzose biotite schist with granitized schist bands
—292+75 Tourmaline pegmatite
—292+50 Injection gneiss with tourmaline.
—292+25 Tourmaline pegmatite
—292+00 Quartzose biotite schist
—291+75 Quartzose biotite schist.
—291+50 Tourmaline pegmatite
—291+25 Feldspathic schist with pegmatite.
—291+00 Biotite schist with tourmaline pegmatite
—290+75 Quartzose biotite schist
—290+50 Biotite schist with pegmatite.
—290+25 Biotite schist with pegmatite.
—290+00 Pegmatite band with biotite schist.


GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
LOCATION AND DESCRIPTION OF SPECIMEN
Water comes from low angle joints dip east nearly parallel to the slope. Water contains a small amount of H_2S which forms a white scum on the rock surface.
Muscovite care in pegmatite.
Peculiar sulphide, chlorite, calcite vein cut the pegmatite.
Foliation dip 11°E
Foliation Strike N16°W Dip 8°E.
Low angle crush zone disappears.
Tourmaline muscovite pegmatite
Foliation dip 17°E.
Crushing
Open fracture contains calcite.
Tourmaline pegmatite.
Coarse calcite with some broken rock
Strike direction N14°W contact between schist and pegmatite. Probably the former. Lookout's gyrm
Foliation dip 10°E
Tourmaline pegmatite
A partial replacement pegmatite lens which contains schist streaks which are nearly horizontal while the schist bands on the outside are curved around
6' Massive quartz, chloritic along border
west side down.
Xenoliths of schist hardly touched by replacement.
Quartz vein.
6' displacement, west side down
west side down.
Str. N10°E, Dip 22°W
Obscure
Crush zone
Rock is blocky and wet.
Horizontal Strike East side moved South
NORTH
SOUTH
Strike N14°E Foliation Dip 10°E
At most no pegmatite
Foliation dip 12°E
Southwest dipping joints still occur
Foliation dip 10°E
Green bands cut by west dipping joints in contact with brownish material.
Green bands with red garnet goes to the schist a banded effect
A string of pegmatite lenses
Occasional pegmatite lenses
Foliation dip 12°E
Pegmatite is about 1% of entire mass.
It is quite common throughout to have the green bands expanded into lens shapes with massive quartz apparently of pegmatitic origin irregularly placed in the center.
Foliation dip 12°E
west side down.
Dip 8°E (in section)
Massive quartz
1½'-2' massive white quartz
Scaling roof
Slight tendency to scaling in the roof
Horizontal strike. Contains calcite with chlorite
Faint strike, but almost no visible displacement.
Tunnel N86°33'W.
LEGEND
PEGMATITE
PAXTON TYPE SCHIST
PAXTON TYPE INJECTION SCHIST
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 310+00 TO 320+00
20 10 0 20 40 FT.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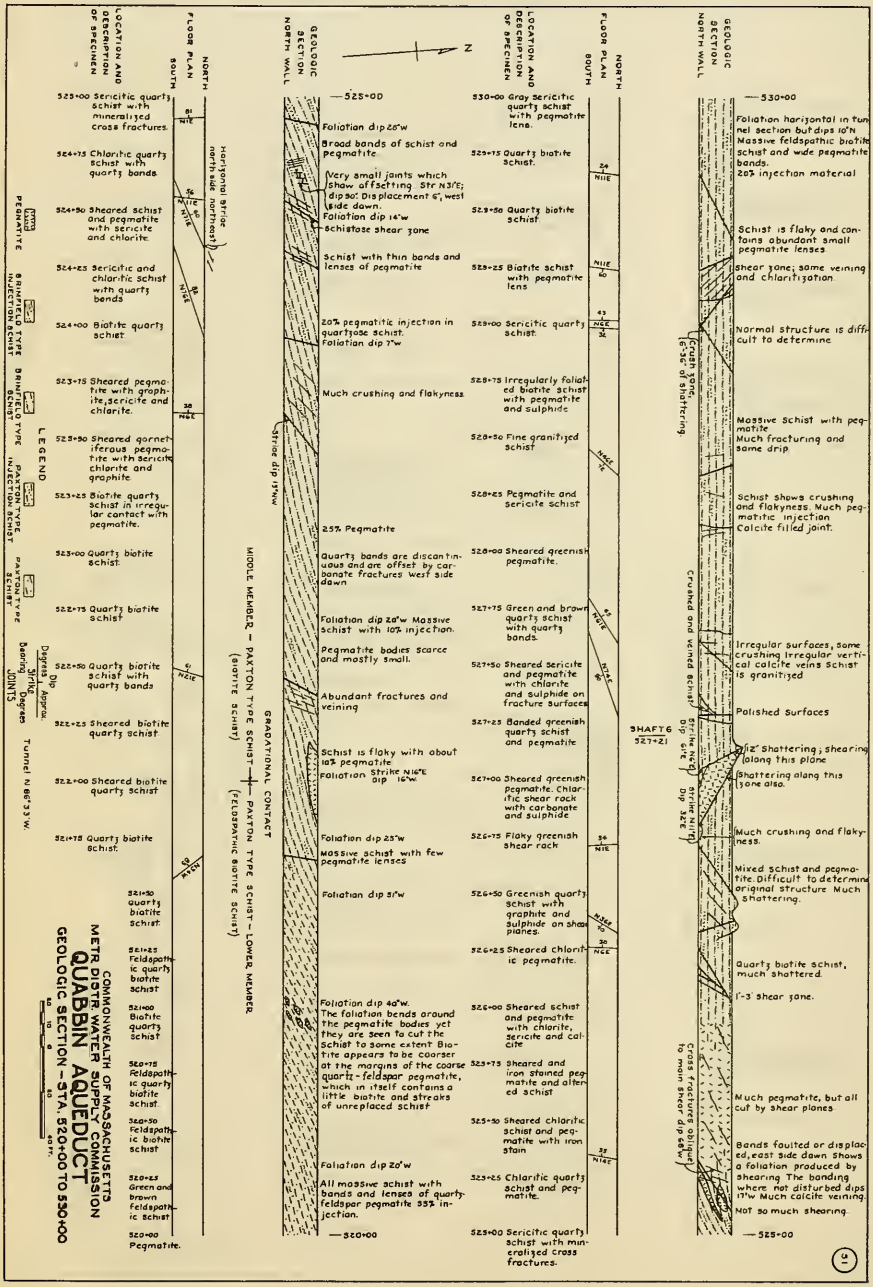
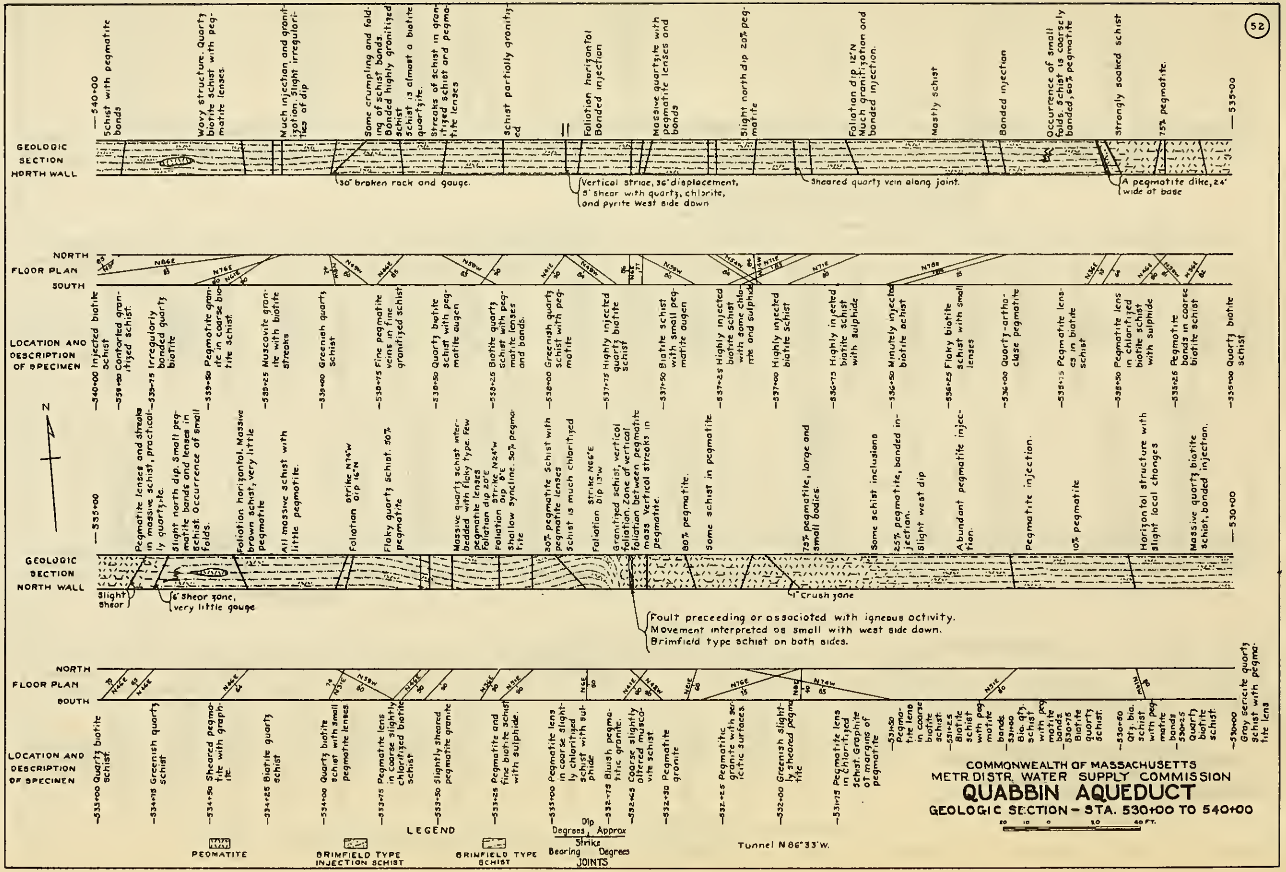
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 500+00 TO 510+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
510+00
505+00
500+00
Pegmatite with large tourmaline crystals.
More pegmatite in large lenses.
Exact contacts not visible
Foliation strike N66°E. dip 13°E.
Strike N16°E; Dip 6°W
Lateral displacement, east side has moved north. Str. N0°E; dip 56°W
Foliation dip 4°N.
Banded injection, many fractures. Rock is more massive to the east
Horizontal fluting
1/8 calcite vein. Str. N14°W; Dip 71°W
Foliation horizontal.
Horizontal striae, west side north.
Horizontal movement, north wall west
510+00 Pegmatite lenses containing muscovite in banded feldspathic biotite schist.
509+75 Pegmatite with coarse muscovite and biotite with chloritized fractures
509+50 Pegmatite with tourmaline
509+25 Feldspathic biotite schist with chlorite and sericite
509+00 Feldspathic biotite schist with quartz pegmatite band.
508+75 Feldspathic biotite schist.
508+50 Feldspathic biotite schist with pegmatite band.
508+25 Feldspathic quartz biotite schist.
508+00 Feldspathic biotite schist with quartz pegmatite bands containing garnet
507+75 Greenish feldspathic biotite schist.
507+50 Muscovite pegmatite lens and feldspathic biotite schist
507+25 Gray sericitic feldspathic schist
507+00 Feldspathic biotite schist.
506+75 Feldspathic biotite schist
506+50 Pegmatite with muscovite, biotite and tourmaline.
506+25 Pegmatite with mica.
506+00 Feldspathic biotite schist
505+75 Feldspathic biotite schist.
505+50 Coarse pegmatite with coarse biotite.
505+25 Feldspathic biotite schist.
505+00 Feldspathic biotite schist.
Foliation horizontal. Lenses and bands of pegmatite
About 25% pegmatite.
Foliation dip 7°W.
Gouge
10% pegmatite
Some lenses appear to be entirely injection as the foliation bends sharply around the pegmatite. In others there is very little bending and perhaps there has been from 1/2 to 3/4 replacement.
Drag indicates west side down. 1/2"-4" crushed rock
1/8"-1/4" calcite vein cuts quartz banding Strike N4°W; Dip 66°W.
4' of crushed and chloritized rock west side down.
Drag indicates east side down.
Fractures and calcite veining normal to foliation. Strike N1°E; Dip 66°E. West wall has moved north.
Horizontal striae Striae N11°E; Dip 69°W
Striae horizontal, north wall east.
505+00 Feldspathic biotite schist
504+75 Feldspathic biotite schist.
504+50 Feldspathic biotite schist.
504+25 Feldspathic biotite schist
504+00 Feldspathic biotite schist with pegmatite augen.
503+75 Feldspathic biotite schist.
503+50 Pegmatite in greenish feldspathic schist.
503+25 Feldspathic biotite schist with numerous pegmatite bands and lenses.
503+00 Feldspathic biotite schist with thin quartz band
502+75 Greenish feldspathic schist with chlorite and calcite
502+50 Coarse pegmatite
502+25 Feldspathic biotite schist with thin quartz bands
502+00 Feldspathic biotite schist.
501+75 Feldspathic biotite schist with quartz bands
501+50 Pegmatite lens and feldspathic bio. schist
501+25 Feldspathic biotite schist with qtz bands
501+00 Feldspathic biotite schist with qtz bands
500+75 Feldspathic biotite schist with peg bands
500+50 Pegmatite.
500+25 Feldspathic biotite schist with pegmatite
500+00 Coarse feldspathic biotite schist
LEGEND
PEGMATITE
PAXTON TYPE SCHIST
PAXTON TYPE INJECTION SCHIST
Dip Degrees
Approx.
Strike
Bearing
Degrees
JOINTS
Tunnel N86°33'W.
20 10 0 20 40 FT.



COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 520+00 TO 530+00
LOCATION AND DESCRIPTION OF SPECIMEN
FLOOR PLAN
SOUTH
NORTH
GEOLOGIC SECTION NORTH WALL
N
LEGEND
PEGMATITE
BRIMFIELD TYPE INJECTION SCHIST
BRINFIELD TYPE SCHIST
PAXTON TYPE INJECTION SCHIST
PAXTON TYPE SCHIST
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel N 86°33'W.
Horizontal Striae north side northeast
525+00 Sericitic quartz schist with mineralized cross fractures.
524+75 Chloritic quartz schist with quartz bands.
524+50 Sheared schist and pegmatite with sericite and chlorite.
524+25 Sericitic and chloritic schist with quartz bands
524+00 Biotite quartz schist.
523+75 Sheared pegmatite with graphite, sericite and chlorite.
523+50 Sheared garnetiferous pegmatite with sericite chlorite and graphite.
523+25 Biotite quartz schist in irregular contact with pegmatite.
523+00 Quartz biotite schist.
522+75 Quartz biotite schist
522+50 Quartz biotite schist with quartz bands
522+25 Sheared biotite quartz schist
522+00 Sheared biotite quartz schist
521+75 Quartz biotite schist.
521+50 Quartz biotite schist.
521+25 Feldspathic quartz biotite schist
521+00 Biotite quartz schist
520+75 Feldspathic quartz biotite schist.
520+50 Feldspathic biotite schist
520+25 Green and brown feldspathic schist
520+00 Pegmatite.
MIDDLE MEMBER - PAXTON TYPE SCHIST (BIOTITE SCHIST)
PAXTON TYPE SCHIST - LOWER MEMBER (FELDSPATHIC BIOTITE SCHIST)
GRADATIONAL CONTACT
Striae dip 15°NW
525+00
Foliation dip 28°W
Broad bands of schist and pegmatite
Very small joints which show offsetting. Str N31°E; dip 90°. Displacement 6", west side down.
Foliation dip 14°W
Schistose shear zone
Schist with thin bands and lenses of pegmatite
20% pegmatitic injection in quartzose schist.
Foliation dip 7°W
Much crushing and flakyness.
25% Pegmatite
Quartz bands are discontinuous and are offset by carbonate fractures west side down
Foliation dip 20°W Massive schist with 10% injection.
Pegmatite bodies scarce and mostly small.
Abundant fractures and veining
Schist is flaky with about 10% pegmatite
Foliation Strike N16°E Dip 16°W.
Foliation dip 25°W
Massive schist with few pegmatite lenses
Foliation dip 51°W
Foliation dip 40°W. The foliation bends around the pegmatite bodies yet they are seen to cut the schist to some extent. Biotite appears to be coarser at the margins of the coarse quartz-feldspar pegmatite, which in itself contains a little biotite and streaks of unreplaced schist
Foliation dip 20°W
All massive schist with bands and lenses of quartz-feldspar pegmatite 55% injection.
520+00
530+00 Gray sericitic quartz schist with pegmatite lens.
529+75 Quartz biotite schist.
529+50 Quartz biotite schist.
529+25 Biotite schist with pegmatite lens
529+00 Sericitic quartz schist.
528+75 Irregularly foliated biotite schist with pegmatite and sulphide
528+50 Fine granitized schist
528+25 Pegmatite and sericite schist
528+00 Sheared greenish pegmatite.
527+75 Green and brown quartz schist with quartz bands.
527+50 Sheared sericite and pegmatite with chlorite and sulphide on fracture surfaces
527+25 Banded greenish quartz schist and pegmatite
527+00 Sheared greenish pegmatite. Chloritic shear rock with carbonate and sulphide
526+75 Flaky greenish shear rock
526+50 Greenish quartz schist with graphite and sulphide on shear planes.
526+25 Sheared chloritic pegmatite.
526+00 Sheared schist and pegmatite with chlorite, sericite and calcite
525+75 Sheared and iron stained pegmatite and altered schist
525+50 Sheared chloritic schist and pegmatite with iron stain
525+25 Chloritic quartz schist and pegmatite.
525+00 Sericitic quartz schist with mineralized cross fractures.
530+00
Foliation horizontal in tunnel section but dips 10°N Massive feldspathic biotite schist and wide pegmatite bands.
20% injection material
Schist is flaky and contains abundant small pegmatite lenses
Shear zone; some veining and chloritization
Normal structure is difficult to determine
Crush zone, 6"-36" of shattering.
Massive schist with pegmatite
Much fracturing and some drip
Schist shows crushing and flakyness. Much pegmatitic injection
Calcite filled joint.
Crushed and veined schist
Irregular surfaces, some crushing Irregular vertical calcite veins Schist is granitized
Polished surfaces
SHAFT 6
527+21
Strike N6°E Dip 61°E
12" Shattering; shearing along this plane
Shattering along this zone also.
Strike N11°E Dip 32°E
Much crushing and flakyness.
Mixed schist and pegmatite. Difficult to determine original structure Much shattering.
Quartz biotite schist, much shattered.
1'-3' shear zone.
Cross fractures oblique to main shear dip 68°W
Much pegmatite, but all cut by shear planes
Bands faulted or displaced, east side down shows a foliation produced by shearing The banding where not disturbed dips 17°W Much calcite veining.
Not so much shearing.
525+00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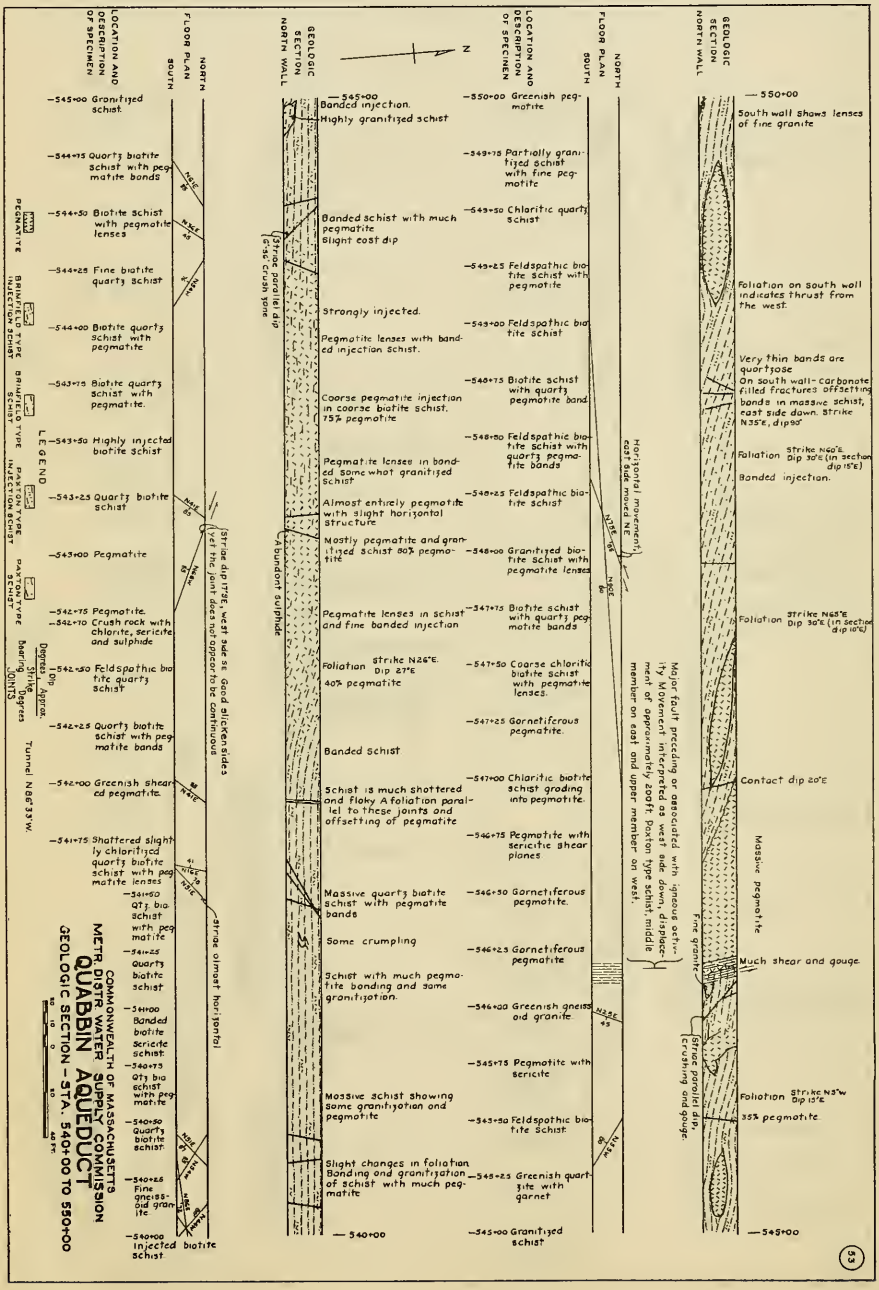
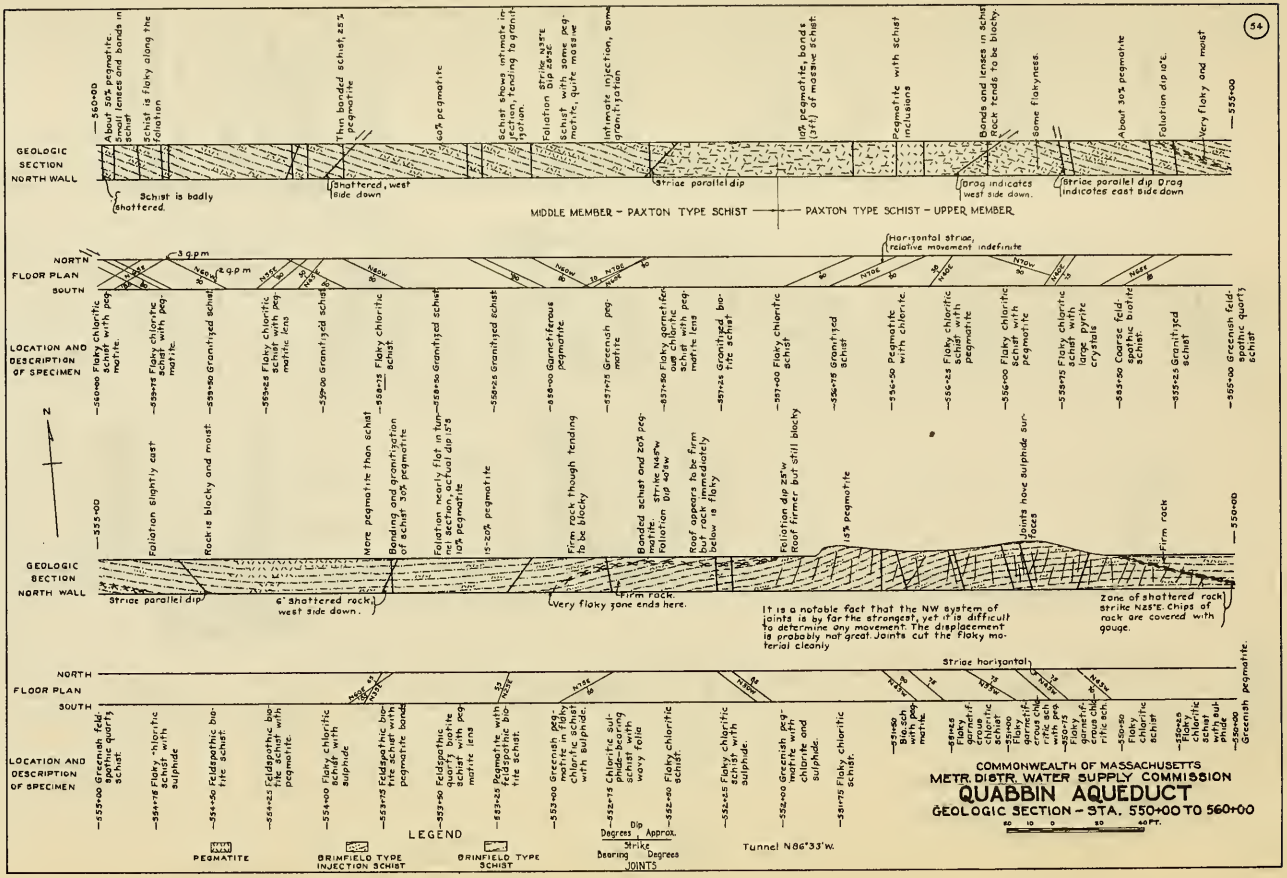
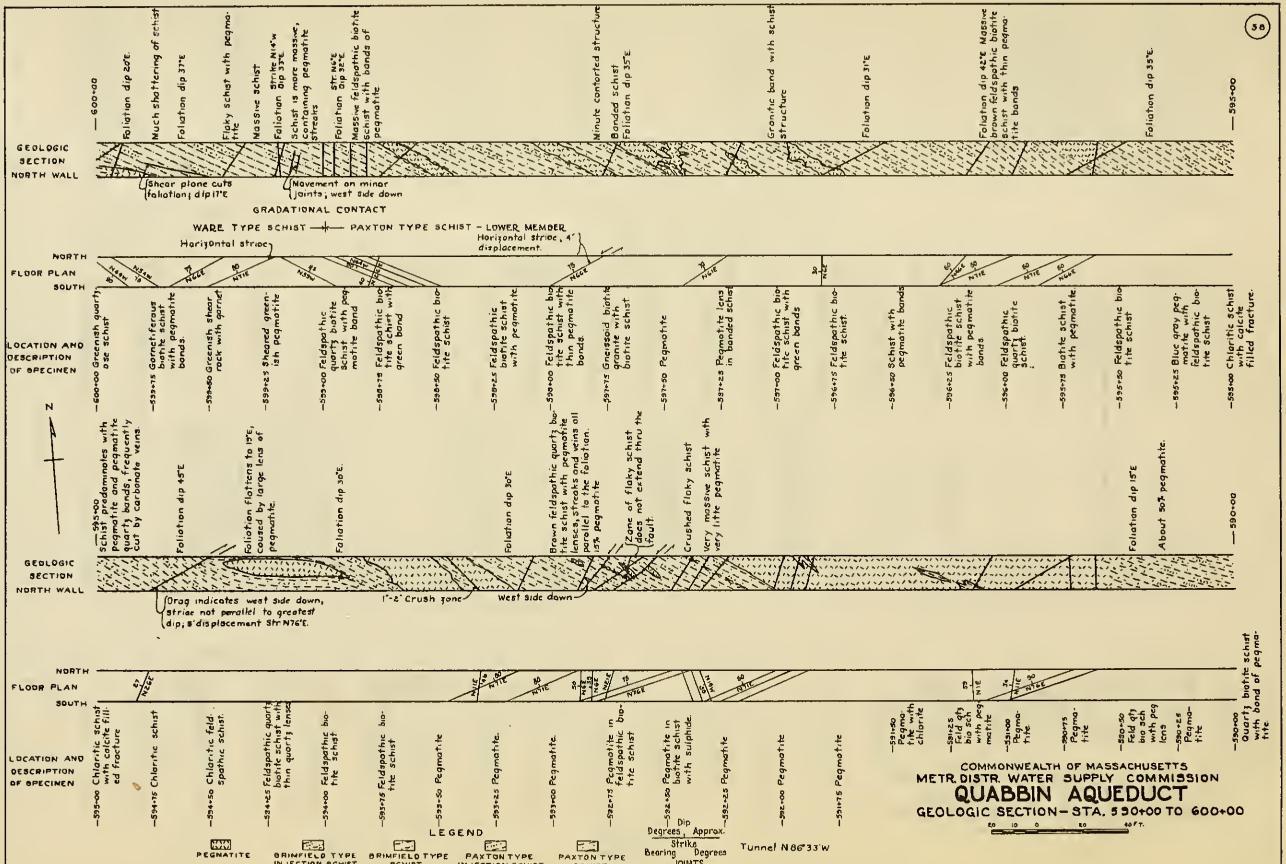
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 530+00 TO 540+00
20 10 0 20 40 FT.
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN NORTH SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
540+00
535+00
530+00
Schist with pegmatite bands
Wavy structure. Quartz biotite schist with pegmatite lenses.
Much injection and granitization. Slight irregularities of dip
Some crumpling and folding of schist bands. Banded highly granitized schist
Schist is almost a biotite quartzite.
Streaks of schist in granitized schist and pegmatite lenses
Schist partially granitized
Foliation horizontal. Banded injection
Massive quartzite with pegmatite lenses and bands
Slight north dip 20% pegmatite
Foliation dip 12°N. Much granitization and banded injection.
Mostly schist
Banded injection
Occurrence of small folds. Schist is coarsely banded, 60% pegmatite
Strongly soaked schist
75% pegmatite.
30" broken rock and gouge.
Vertical striae, 36" displacement, 5" shear with quartz, chlorite, and pyrite west side down
Sheared quartz vein along joint.
A pegmatite dike, 24" wide at base
540+00 Injected biotite schist
539+90 Contorted granitized schist.
539+75 Irregularly banded quartz biotite
539+50 Pegmatite granite in coarse biotite schist.
539+25 Muscovite granite with biotite streaks
539+00 Greenish quartz schist
538+75 Fine pegmatite veins in fine granitized schist
538+50 Quartz biotite schist with pegmatite augen
538+25 Biotite quartz schist with pegmatite lenses and bands.
538+00 Greenish quartz schist with pegmatite
537+75 Highly injected quartz biotite schist
537+50 Biotite schist with small pegmatite augen
537+25 Highly injected biotite schist with some chlorite and sulphide
537+00 Highly injected biotite schist
536+75 Highly injected biotite schist with sulphide
536+50 Minutely injected biotite schist
536+25 Flaky biotite schist with small lenses
536+00 Quartz-orthoclase pegmatite
535+75 Pegmatite lenses in biotite schist
535+50 Pegmatite lens in chloritized biotite schist with sulphide
535+25 Pegmatite bands in coarse biotite schist
535+00 Quartz biotite schist
Pegmatite lenses and streaks in massive schist, practically quartzite.
Slight north dip. Small pegmatite bands and lenses in schist. Occurrence of small folds.
Foliation horizontal. Massive brown schist, very little pegmatite
All massive schist with little pegmatite.
Foliation strike N14°W dip 16°N
Flaky quartz schist. 50% pegmatite
Massive quartz schist interbedded with flaky type. Few pegmatite lenses
Foliation dip 20°E
Foliation strike N24°W dip 8°E
Shallow syncline. 50% pegmatite
30% pegmatite. Schist with pegmatite lenses
Schist is much chloritized
Foliation strike N66°E dip 13°W
Granitized schist, vertical foliation. Zone of vertical foliation between pegmatite mass. Vertical streaks in pegmatite.
80% pegmatite.
Some schist in pegmatite
75% pegmatite, large and small bodies.
Some schist inclusions
25% pegmatite, banded injection.
Slight west dip
Abundant pegmatite injection.
Pegmatite injection.
10% pegmatite
Horizontal structure with slight local changes
Massive quartz biotite schist, banded injection.
Slight shear
6" shear zone, very little gouge
1" crush zone
Fault preceeding or associated with igneous activity. Movement interpreted as small with west side down. Brimfield type schist on both sides.
535+00 Quartz biotite schist.
534+75 Greenish quartz schist
534+50 Sheared pegmatite with graphite.
534+25 Biotite quartz schist
534+00 Quartz biotite schist with small pegmatite lenses
533+75 Pegmatite lens in coarse slightly chloritized biotite schist
533+50 Slightly sheared pegmatite granite
533+25 Pegmatite and fine biotite schist with sulphide.
533+00 Pegmatite lens in coarse slightly chloritized schist with sulphide
532+75 Bluish pegmatitic granite.
532+65 Coarse slightly altered muscovite schist.
532+50 Pegmatite granite
532+25 Pegmatitic granite with sericitic surfaces.
532+00 Greenish slightly sheared pegmatite
531+75 Pegmatite lens in chloritized schist. Graphite at margins of pegmatite
531+50 Pegmatite lens in coarse biotite schist.
531+25 Biotite schist with pegmatite bands
531+00 Bio. qtz. schist with pegmatite bands
530+75 Biotite quartz schist.
530+50 Qtz. bio. schist with pegmatite bands
530+25 Quartz biotite schist.
530+00 Gray sericite quartz schist with pegmatite lens
LEGEND
PEGMATITE
BRIMFIELD TYPE INJECTION SCHIST
BRIMFIELD TYPE SCHIST
Dip Degrees, Approx Strike
Bearing Degrees
JOINTS
Tunnel N 86°33' W.
N

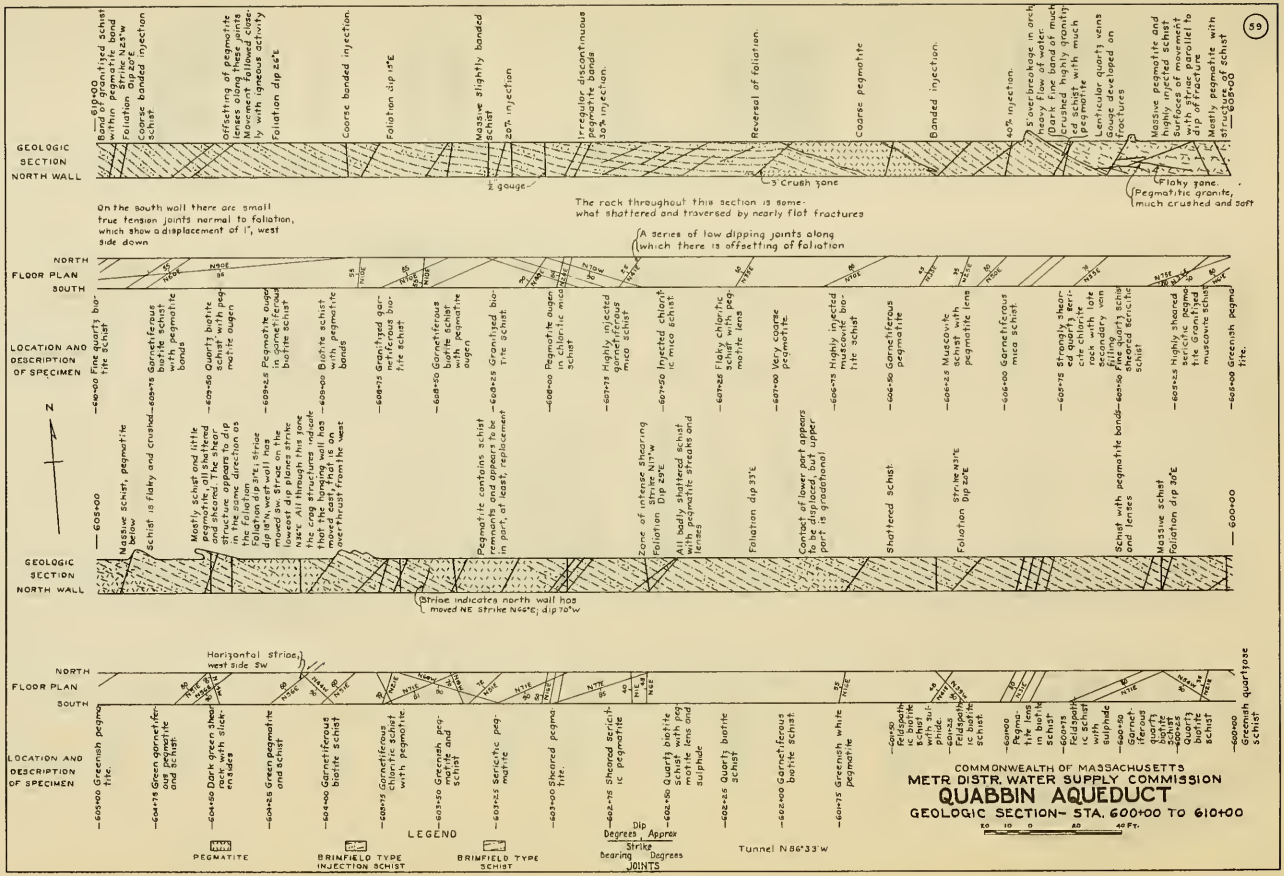


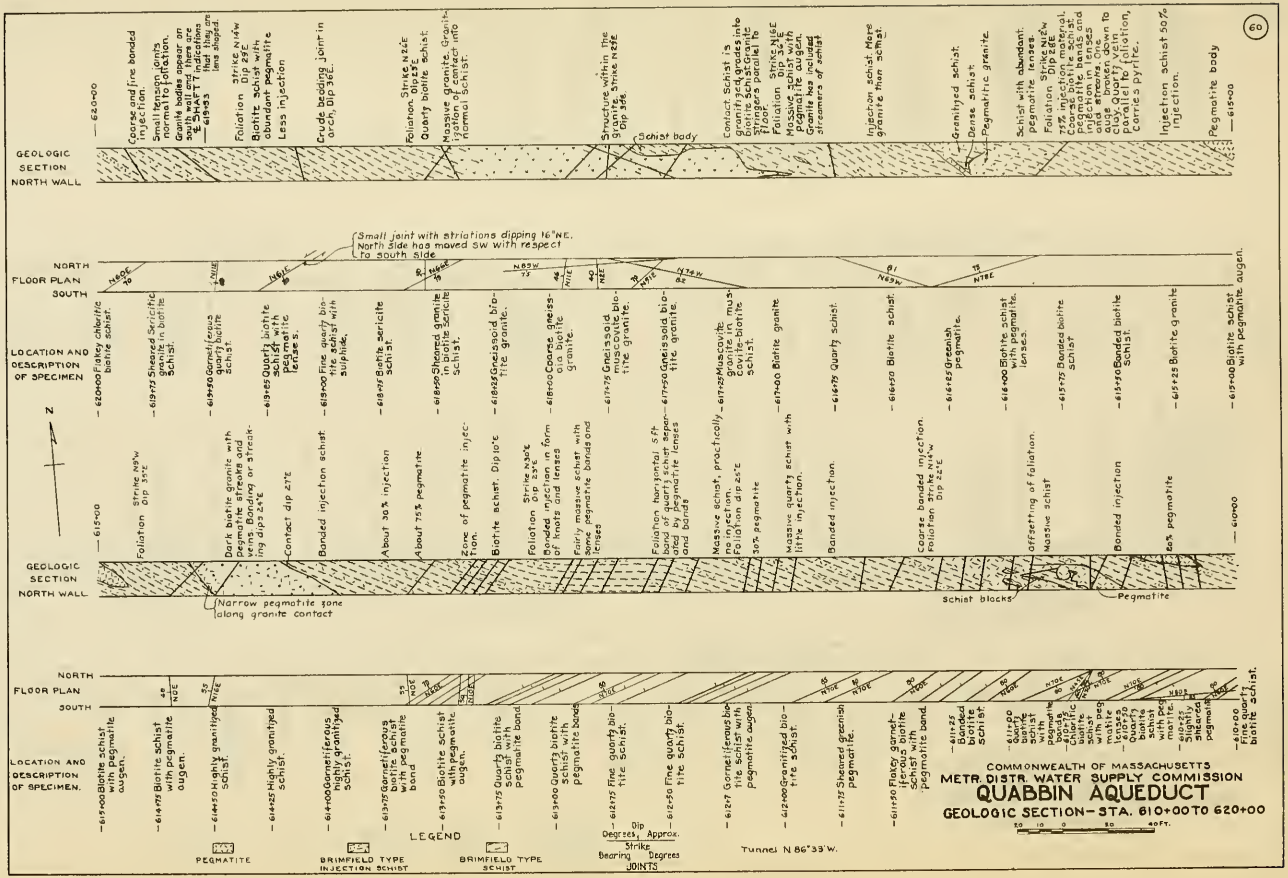
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 540+00 TO 550+00
LOCATION AND DESCRIPTION OF SPECIMEN
FLOOR PLAN
SOUTH
NORTH
GEOLOGIC SECTION
NORTH WALL
N
LEGEND
PEGMATITE
BRIMFIELD TYPE INJECTION SCHIST
BRIMFIELD TYPE SCHIST
PAXTON TYPE INJECTION SCHIST
PAXTON TYPE SCHIST
Dip Degrees
Approx. Strike Degrees
Bearing JOINTS
Tunnel N86°33'W.
–545+00 Granitized schist.
–544+75 Quartz biotite schist with pegmatite bands
–544+50 Biotite schist with pegmatite lenses
–544+25 Fine biotite quartz schist
–544+00 Biotite quartz schist with pegmatite
–543+75 Biotite quartz schist with pegmatite.
–543+50 Highly injected biotite schist
–543+25 Quartz biotite schist
–543+00 Pegmatite
–542+75 Pegmatite.
–542+70 Crush rock with chlorite, sericite and sulphide
–542+50 Feldspathic biotite quartz schist
–542+25 Quartz biotite schist with pegmatite bands
–542+00 Greenish sheared pegmatite.
–541+75 Shattered slightly chloritized quartz biotite schist with pegmatite lenses
–541+50 Qtz. bio. schist with pegmatite
–541+25 Quartz biotite schist
–541+00 Banded biotite sericite schist.
–540+75 Qtz bio schist with pegmatite
–540+50 Quartz biotite schist.
–540+25 Fine gneissoid granite
–540+00 Injected biotite schist.
Striae dip 17°SE, west side SE. Good slickensides yet the joint does not appear to be continuous
Striae almost horizontal
–545+00 Banded injection.
Highly granitized schist
Banded schist with much pegmatite
Slight east dip
Striae parallel dip 6°-56' crush zone
Strongly injected.
Pegmatite lenses with banded injection schist.
Coarse pegmatite injection in coarse biotite schist. 75% pegmatite
Pegmatite lenses in banded somewhat granitized schist
Almost entirely pegmatite with slight horizontal structure
Mostly pegmatite and granitized schist 80% pegmatite
Abundant sulphide
Pegmatite lenses in schist and fine banded injection
Foliation strike N26°E. Dip 27°E
40% pegmatite
Banded schist
Schist is much shattered and flaky A foliation parallel to these joints and offsetting of pegmatite
Massive quartz biotite schist with pegmatite bands
Some crumpling
Schist with much pegmatite banding and some granitization.
Massive schist showing some granitization and pegmatite
Slight changes in foliation Banding and granitization of schist with much pegmatite
–540+00
–550+00 Greenish pegmatite
–549+75 Partially granitized schist with fine pegmatite
–549+50 Chloritic quartz schist
–549+25 Feldspathic biotite schist with pegmatite
–549+00 Feldspathic biotite schist
–548+75 Biotite schist with quartz pegmatite band
–548+50 Feldspathic biotite schist with quartz pegmatite bands
–548+25 Feldspathic biotite schist
–548+00 Granitized biotite schist with pegmatite lenses
–547+75 Biotite schist with quartz pegmatite bands
–547+50 Coarse chloritic biotite schist with pegmatite lenses.
–547+25 Garnetiferous pegmatite.
–547+00 Chloritic biotite schist grading into pegmatite.
–546+75 Pegmatite with sericitic shear planes
–546+50 Garnetiferous pegmatite.
–546+25 Garnetiferous pegmatite
–546+00 Greenish gneissoid granite
–545+75 Pegmatite with sericite
–545+50 Feldspathic biotite schist
–545+25 Greenish quartzite with garnet
–545+00 Granitized schist
Horizontal movement, east side moved NE
Major fault preceding or associated with igneous activity Movement interpreted as west side down, displacement of approximately 200ft. Paxton type schist, middle member on east and upper member on west.
–550+00
South wall shows lenses of fine granite
Foliation on south wall indicates thrust from the west.
Very thin bands are quartzose
On south wall – carbonate filled fractures offsetting bands in massive schist, east side down. Strike N35°E, dip 90°
Foliation Strike N60°E Dip 30°E (in section dip 15°E)
Banded injection.
Foliation Strike N65°E Dip 30°E (in section dip 10°E)
Contact dip 20°E
Massive pegmatite
Fine granite
Much shear and gouge.
Striae parallel dip, crushing and gouge.
Foliation Strike N5°W Dip 15°E
35% pegmatite
–545+00

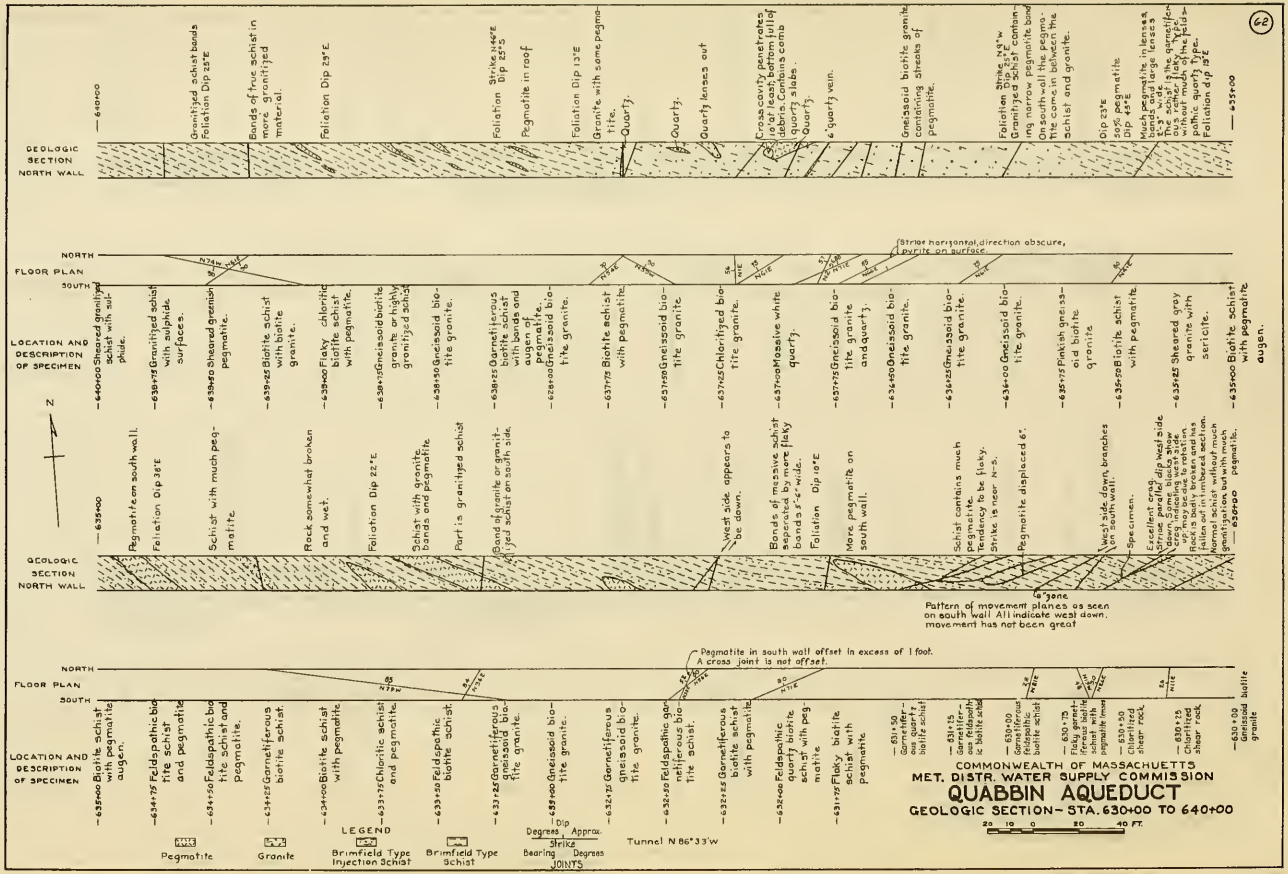

GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
LOCATION AND DESCRIPTION OF SPECIMEN
MIDDLE MEMBER - PAXTON TYPE SCHIST
PAXTON TYPE SCHIST - UPPER MEMBER
Schist is badly shattered.
Shattered, west side down
Striae parallel dip
Drag indicates west side down.
Striae parallel dip Drag indicates east side down
Horizontal striae, relative movement indefinite
Zone of shattered rock strike N25°E. Chips of rock are covered with gouge.
It is a notable fact that the NW system of joints is by far the strongest, yet it is difficult to determine any movement. The displacement is probably not great. Joints cut the Floky material cleanly
Tunnel N86°33'W.
LEGEND
PEGMATITE
BRINFIELD TYPE INJECTION SCHIST
BRINFIELD TYPE SCHIST
JOINTS
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 550+00 TO 560+00



COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 530+00 TO 600+00
58
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
600+00
Foliation dip 20°E.
Much shattering of schist
Foliation dip 37°E
Flaky schist with pegmatite
Massive schist
Foliation Strike N14°W dip 33°E
Schist is more massive, containing pegmatite streaks
Foliation Str. N6°E dip 32°E
Massive feldspathic biotite schist with bands of pegmatite
Minute contorted structure
Banded schist
Foliation dip 35°E
Granitic band with schist structure
Foliation dip 31°E
Foliation dip 42°E Massive brown feldspathic biotite schist with thin pegmatite bands
Foliation dip 35°E.
595+00
Shear plane cuts foliation; dip 17°E
Movement on minor joints; west side down
GRADATIONAL CONTACT
WARE TYPE SCHIST — PAXTON TYPE SCHIST – LOWER MEMBER
Horizontal striae
Horizontal striae, 4' displacement.
600+00 Greenish quartzose schist
599+75 Garnetiferous biotite schist with pegmatite bands.
599+50 Greenish shear rock with garnet
599+25 Sheared greenish pegmatite
599+00 Feldspathic quartz biotite schist with pegmatite band
598+75 Feldspathic biotite schist with green band
598+50 Feldspathic biotite schist
598+25 Feldspathic biotite schist with pegmatite
598+00 Feldspathic biotite schist with thin pegmatite bands.
597+75 Gneissoid biotite granite with biotite schist
597+50 Pegmatite
597+25 Pegmatite lens in banded schist
597+00 Feldspathic biotite schist with green bands
596+75 Feldspathic biotite schist.
596+50 Schist with pegmatite bands
596+25 Feldspathic biotite schist with pegmatite bands
596+00 Feldspathic quartz biotite schist.
595+75 Biotite schist with pegmatite
595+50 Feldspathic biotite schist
595+25 Blue gray pegmatite with feldspathic biotite schist
595+00 Chloritic schist with calcite filled fracture.
N
595+00
Schist predominates with pegmatite and pegmatite quartz bands, frequently cut by carbonate veins.
Foliation dip 45°E
Foliation flattens to 15°E, caused by large lens of pegmatite.
Foliation dip 30°E.
Foliation dip 30°E
Brown feldspathic quartz biotite schist with pegmatite lenses, streaks and veins all parallel to the foliation. 15% pegmatite
Zone of flaky schist does not extend thru the fault.
Crushed flaky schist
Very massive schist with very litte pegmatite
Foliation dip 15°E
About 50% pegmatite.
590+00
Drag indicates west side down, striae not parallel to greatest dip; 8' displacement Str N76°E.
1"-2" Crush zone
West side down
595+00 Chloritic schist with calcite filled fracture
594+75 Chloritic schist
594+50 Chloritic feldspathic schist.
594+25 Feldspathic quartz biotite schist with thin quartz lenses
594+00 Feldspathic biotite schist
593+75 Feldspathic biotite schist
593+50 Pegmatite
593+25 Pegmatite.
593+00 Pegmatite.
592+75 Pegmatite in feldspathic biotite schist
592+50 Pegmatite in biotite schist with sulphide.
592+25 Pegmatite
592+00 Pegmatite
591+75 Pegmatite
591+50 Pegmatite with chlorite
591+25 Feld qtz bio sch with pegmatite
591+00 Pegmatite
590+75 Pegmatite
590+50 Feld qtz bio sch with peg lens
590+25 Pegmatite
590+00 Quartz biotite schist with band of pegmatite.
LEGEND
PEGMATITE
BRIMFIELD TYPE INJECTION SCHIST
BRIMFIELD TYPE SCHIST
PAXTON TYPE INJECTION SCHIST
PAXTON TYPE SCHIST
Dip Degrees, Approx. Strike Bearing Degrees JOINTS
Tunnel N86°33'W


59
GEOLOGIC SECTION NORTH WALL
610+00 Band of granitized schist within pegmatite band
Foliation Strike N25°W Dip 20°E
Coarse banded injection schist
Offsetting of pegmatite lenses along these joints Movement followed closely with igneous activity
Foliation dip 26°E
Coarse banded injection.
Foliation dip 15°E
Massive slightly banded schist
20% injection
Irregular discontinuous pegmatite bands 30% injection.
Reversal of foliation.
Coarse pegmatite
Banded injection.
40% injection.
5' overbreakage in arch, heavy flow of water.
Dark fine band of much crushed highly granitized schist with much pegmatite
Lenticular quartz veins Gouge developed on fractures
Massive pegmatite and highly injected schist Surfaces of movement with striae parallel to dip of fracture
Mostly pegmatite with structure of schist
605+00
½" gouge
3' Crush zone
Flaky zone.
Pegmatitic granite, much crushed and soft
On the south wall there are small true tension joints normal to foliation, which show a displacement of 1", west side down
The rock throughout this section is somewhat shattered and traversed by nearly flat fractures
A series of low dipping joints along which there is offsetting of foliation
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
610+00 Fine quartz biotite schist
609+75 Garnetiferous biotite schist with pegmatite bands
609+50 Quartz biotite schist with pegmatite augen
609+25 Pegmatite augen in garnetiferous biotite schist
609+00 Biotite schist with pegmatite bands
608+75 Granitized garnetiferous biotite schist
608+50 Garnetiferous biotite schist with pegmatite augen
608+25 Granitized biotite schist.
608+00 Pegmatite augen in chloritic mica schist
607+75 Highly injected garnetiferous mica schist
607+50 Injected chloritic mica schist.
607+25 Flaky chloritic schist with pegmatite lens
607+00 Very coarse pegmatite.
606+75 Highly injected muscovite biotite schist
606+50 Garnetiferous pegmatite
606+25 Muscovite schist with pegmatite lens
606+00 Garnetiferous mica schist.
605+75 Strongly sheared quartz sericite chlorite rock with late secondary vein filling
605+50 Fine quartz schist sheared sericitic schist
605+25 Highly sheared sericitic pegmatite Granitized muscovite schist
605+00 Greenish pegmatite.
N
605+00
Massive schist, pegmatite below
Schist is flaky and crushed
Mostly schist and little pegmatite, all shattered and sheared. The shear structure appears to dip in the same direction as the foliation
Foliation dip 31°E; striae dip 18°N, west wall has moved SW. Striae on the lowest dip planes strike N36°E. All through this zone the crag structures indicate that the hanging wall has moved east, that is an overthrust from the west
Pegmatite contains schist remnants and appears to be in part, at least, replacement
Zone of intense shearing Strike N17°W Foliation Dip 29°E
All badly shattered schist with pegmatite streaks and lenses
Foliation dip 33°E
Contact of lower part appears to be displaced, but upper part is gradational
Shattered schist.
Foliation Strike N31°E Dip 20°E
Schist with pegmatite bands and lenses
Massive schist
Foliation dip 30°E
600+00
Striae indicates north wall has moved NE Strike N66°E; dip 70°W
Horizontal striae, west side SW
605+00 Greenish pegmatite.
604+75 Green garnetiferous pegmatite and schist.
604+50 Dark green shear rock with slickensides
604+25 Green pegmatite and schist
604+00 Garnetiferous biotite schist
603+75 Garnetiferous chloritic schist with pegmatite.
603+50 Greenish pegmatite and schist
603+25 Sericitic pegmatite
603+00 Sheared pegmatite.
602+75 Sheared sericitic pegmatite
602+50 Quartz biotite schist with pegmatite lens and sulphide
602+25 Quartz biotite schist
602+00 Garnetiferous biotite schist.
601+75 Greenish white pegmatite
601+50 Feldspathic biotite schist with sulphide.
601+25 Feldspathic biotite schist.
601+00 Pegmatite lens in biotite schist
600+75 Feldspathic schist with sulphide
600+50 Garnetiferous quartz biotite schist
600+25 Quartz biotite schist
600+00 Greenish quartzose schist
LEGEND
PEGMATITE
BRIMFIELD TYPE INJECTION SCHIST
BRIMFIELD TYPE SCHIST
Dip Degrees Approx
Strike Bearing Degrees
JOINTS
Tunnel N86°33'W
COMMONWEALTH OF MASSACHUSETTS
METR DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION- STA. 600+00 TO 610+00
20 10 0 20 40 FT.


60
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 610+00 TO 620+00
20 10 0 20 40 FT.
Tunnel N 86°33' W.
LEGEND
PEGMATITE
BRIMFIELD TYPE INJECTION SCHIST
BRIMFIELD TYPE SCHIST
Dip Degrees, Approx.
Strike Bearing Degrees
JOINTS
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
620+00
Coarse and fine banded injection.
Small tension joints normal to foliation.
Granite bodies appear on south wall and there are indications that they are lens shaped.
℄ SHAFT 7
619+33
Foliation strike N14W Dip 29E
Biotite schist with abundant pegmatite
Less injection
Crude bedding joint in arch, Dip 36E.
Foliation. Strike N26E Dip 25E
Quartz biotite schist.
Massive granite. Granitization of contact into normal schist.
Structure within the granite. Strike N29E Dip 36E.
Schist body
Contact. Schist is granitized, grades into biotite schist. Granite stringers parallel to floor.
Foliation Strike N16E Dip 36E
Massive schist with pegmatite augen. Granite has included streamers of schist
Injection schist. More granite than schist.
Granitized schist.
Dense schist.
Pegmatitic granite.
Schist with abundant pegmatite lenses.
Foliation Strike N16W Dip 28E
75% injection material. Coarse biotite schist. Pegmatite bands and injection in lenses and streaks. One auge broken down to clay. Quartz vein parallel to foliation, carries pyrite.
Injection schist 50% injection.
Pegmatite body
615+00
Small joint with striations dipping 16°NE. North side has moved SW with respect to south side
620+00 Flakey chloritic biotite schist.
619+75 Sheared Sericitic granite in biotite schist.
619+50 Garnetiferous quartz biotite schist.
619+25 Quartz biotite schist with pegmatite lenses.
619+00 Fine quartz biotite schist with sulphide.
618+75 Biotite sericite schist.
618+50 Sheared granite in biotite Sericite schist.
618+25 Gneissoid biotite granite.
618+00 Coarse gneissoid biotite granite.
617+75 Gneissoid muscovite biotite granite.
617+50 Gneissoid biotite granite.
617+25 Muscovite granite in muscovite-biotite schist.
617+00 Biotite granite
616+75 Quartz schist.
616+50 Biotite schist.
616+25 Greenish pegmatite.
616+00 Biotite schist with pegmatite lenses.
615+75 Banded biotite schist
615+50 Banded biotite schist.
615+25 Biotite granite
615+00 Biotite schist with pegmatite augen.
Foliation Strike N9°W Dip 35°E
Dark biotite granite with pegmatite streaks and veins. Banding or streaking dips 24°E
Contact dip 27°E
Banded injection schist.
About 30% injection
About 75% pegmatite
Zone of pegmatite injection.
Biotite schist. Dip 10°E
Foliation Strike N30°E Dip 23°E
Banded injection in form of knots and lenses
Fairly massive schist with some pegmatite bands and lenses
Foliation horizontal. 5 ft band of quartz schist separated by pegmatite lenses and bands
Massive schist, practically no injection. Foliation dip 25°E
30% pegmatite
Massive quartz schist with little injection.
Banded injection.
Coarse banded injection. Foliation Strike N14°W Dip 22°E
Offsetting of foliation.
Massive schist
Banded injection
20% pegmatite
610+00
Narrow pegmatite zone along granite contact
Schist blocks
Pegmatite
615+00 Biotite schist with pegmatite augen.
614+75 Biotite schist with pegmatite augen.
614+50 Highly granitized schist.
614+25 Highly granitized schist.
614+00 Garnetiferous highly granitized schist.
613+75 Garnetiferous biotite schist with pegmatite band
613+50 Biotite schist with pegmatite augen.
613+25 Quartz biotite schist with pegmatite band
613+00 Quartz biotite schist with pegmatite bands
612+75 Fine quartz biotite schist.
612+50 Fine quartz biotite schist.
612+7 Garnetiferous biotite schist with pegmatite augen.
612+00 Granitized biotite schist.
611+75 Sheared greenish pegmatite.
611+50 Flakey garnetiferous biotite schist with pegmatite band.
611+25 Banded biotite schist.
611+00 Quartz biotite schist with pegmatite bands
610+75 Chloritic biotite schist with pegmatite lenses
610+50 Quartz biotite schist with pegmatite.
610+25 Slightly sheared pegmatite
610+00 Fine quartz biotite schist.



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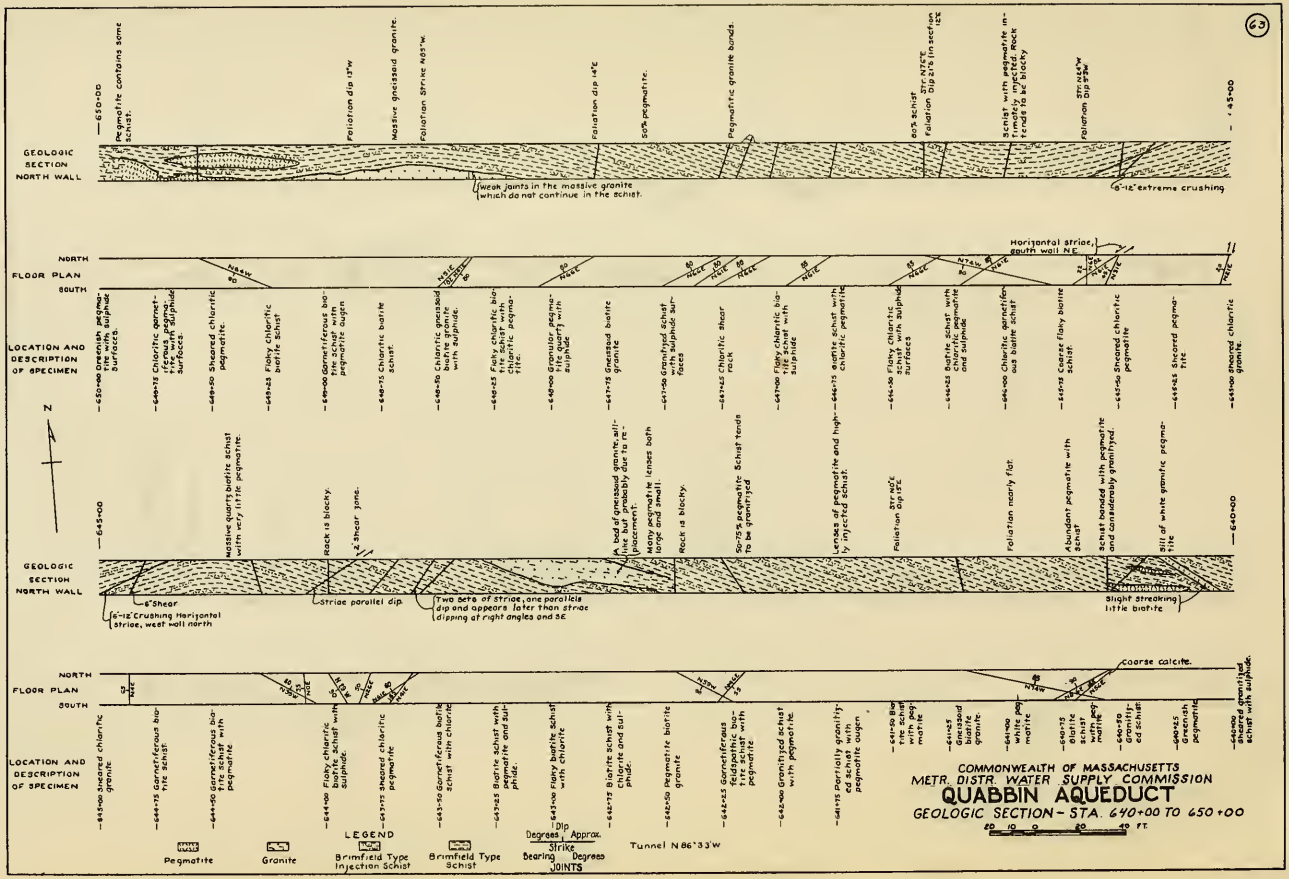
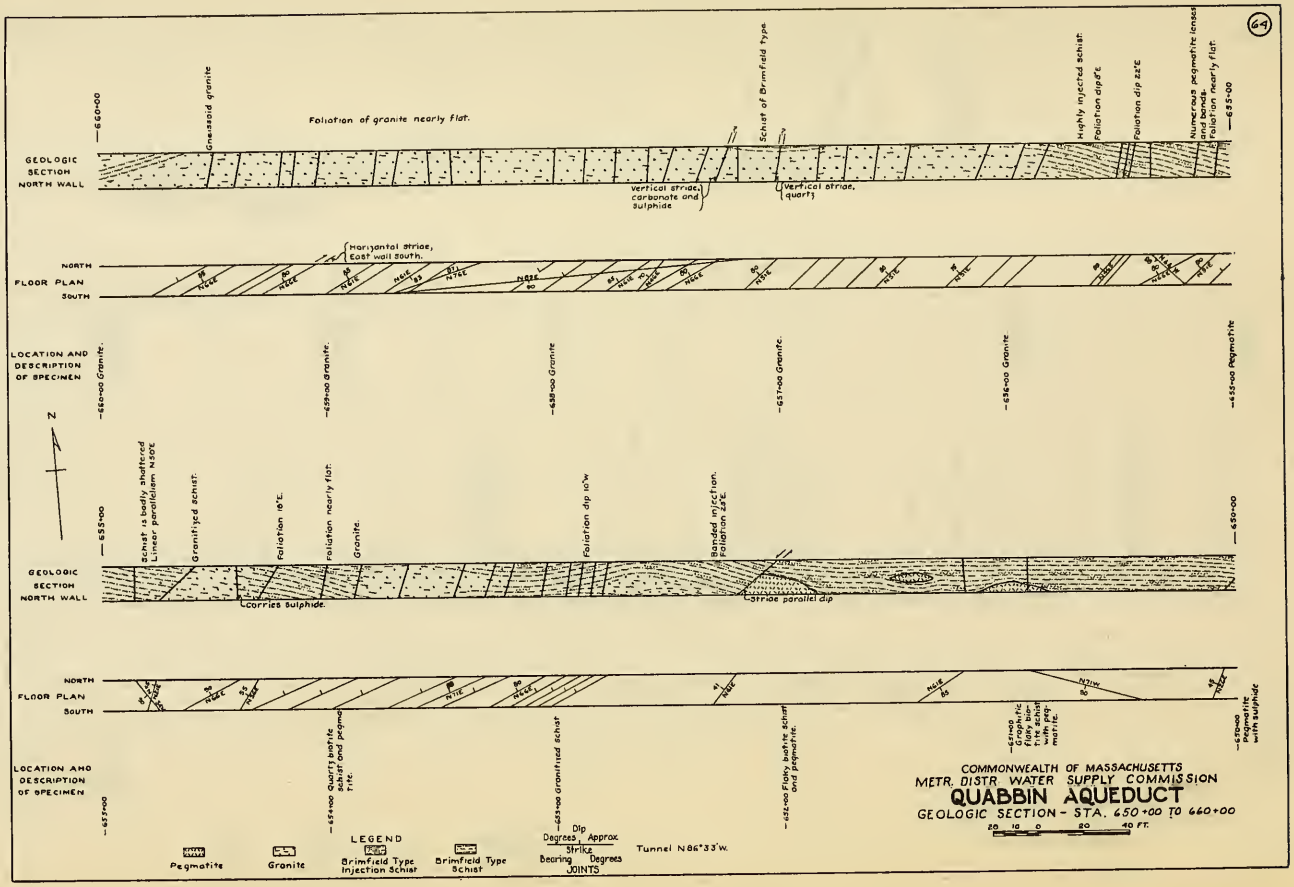
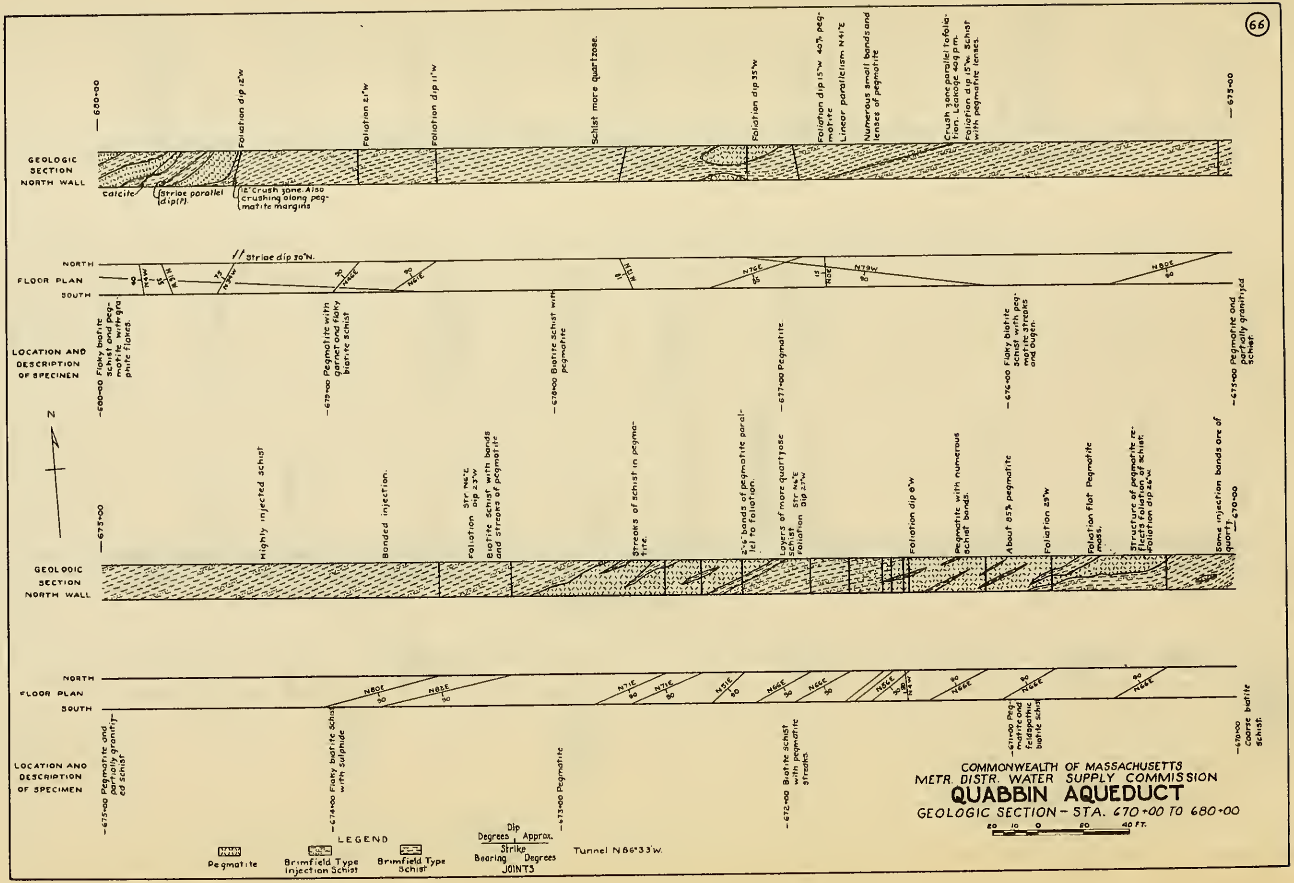
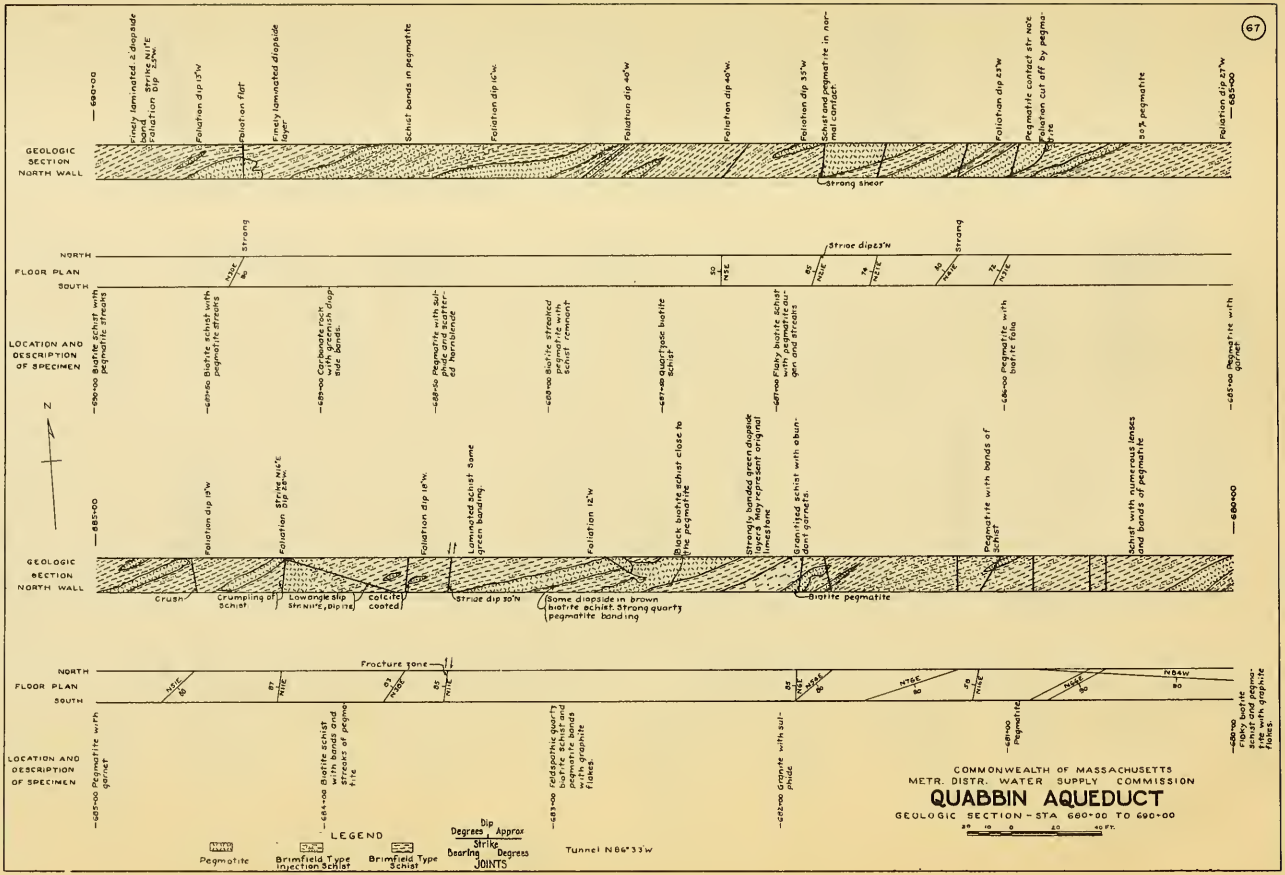
GEOLOGIC SECTION NORTH WALL
— 640+00
Granitized schist bands Foliation Dip 25°E
Bands of true schist in more granitized material.
Foliation Dip 29°E
Foliation Strike N46°E Dip 25°S
Pegmatite in roof
Foliation Dip 13°E
Granite with some pegmatite.
Quartz.
Quartz.
Quartz lenses out
Cross cavity penetrates 10' at least, bottom full of debris. Contains comb quartz slabs.
Quartz.
6" quartz vein.
Gneissoid biotite granite containing streaks of pegmatite.
Foliation Strike N9°W Dip 25°E
Granitized schist containing narrow pegmatite band
On south wall the pegmatite came in between the schist and granite.
Dip 23°E
50% pegmatite
Dip 45°E
Much pegmatite in lenses, bands and large lenses 2'-3' wide
The schist is the garnetiferous rather flaky type without much of the feldspathic quartz type.
Foliation dip 13°E
— 635+00
FLOOR PLAN
NORTH
SOUTH
Strike horizontal, direction obscure, pyrite on surface.
LOCATION AND DESCRIPTION OF SPECIMEN
— 640+00 Sheared granitized schist with sulphide.
— 638+75 Granitized schist with sulphide surfaces.
— 639+50 Sheared greenish pegmatite.
— 639+25 Biotite schist with biotite granite.
— 639+00 Flaky chloritic biotite schist with pegmatite.
— 638+75 Gneissoid biotite granite or highly granitized schist
— 638+50 Gneissoid biotite granite.
— 638+25 Garnetiferous biotite schist with bands and augen of pegmatite.
— 628+00 Gneissoid biotite granite.
— 637+75 Biotite schist with pegmatite
— 637+50 Gneissoid biotite granite
— 637+25 Chloritized biotite granite.
— 637+00 Massive white quartz.
— 637+75 Gneissoid biotite granite and quartz.
— 636+50 Gneissoid biotite granite.
— 636+25 Gneissoid biotite granite.
— 636+00 Gneissoid biotite granite.
— 635+75 Pinkish gneissoid biotite granite
— 635+50 Biotite schist with pegmatite.
— 635+25 Sheared gray granite with sericite.
— 635+00 Biotite schist with pegmatite augen.
N
— 635+00
Pegmatite on south wall.
Foliation Dip 38°E
Schist with much pegmatite
Rock somewhat broken and wet.
Foliation Dip 22°E
Schist with granite bands and pegmatite
Part is granitized schist
Band of granite or granitized schist on south side.
West side appears to be down.
Bands of massive schist seperated by more flaky bands 5'-6" wide.
Foliation Dip 10°E
More pegmatite on south wall.
Schist contains much pegmatite. Tendency to be flaky. Strike is near N-S.
Pegmatite displaced 6".
West side down, branches on south wall.
Specimen.
Excellent crag. Strike parallel dip west side down. Some blocks show crag indicating west side up; may be due to rotation. Rock is badly broken and has fallen out in timbered section. Normal schist without much granitization but with much pegmatite.
— 630+00
6" zone
Pattern of movement planes as seen on south wall All indicate west down. movement has not been great
Pegmatite in south wall offset in excess of 1 foot. A cross joint is not offset.
— 635+00 Biotite schist with pegmatite augen.
— 634+75 Feldspathic biotite schist and pegmatite
— 634+50 Feldspathic biotite schist and pegmatite.
— 634+25 Garnetiferous biotite schist.
— 634+00 Biotite schist with pegmatite
— 633+75 Chloritic schist and pegmatite.
— 633+50 Feldspathic biotite schist.
— 633+25 Garnetiferous gneissoid biotite granite.
— 633+00 Gneissoid biotite granite.
— 632+75 Garnetiferous gneissoid biotite granite.
— 632+50 Feldspathic garnetiferous biotite schist.
— 632+25 Garnetiferous biotite schist with pegmatite
— 632+00 Feldspathic quartz biotite schist with pegmatite
— 631+75 Flaky biotite schist with pegmatite
— 631+50 Garnetiferous quartz biotite schist
— 631+25 Garnetiferous feldspathic biotite schist
— 630+00 Garnetiferous feldspathic biotite schist
— 630+75 Flaky garnetiferous biotite schist with pegmatite lenses
— 630+50 Chloritized shear rock
— 630+25 Chloritized shear rock
— 630+00 Gneissoid biotite granite
LEGEND
Pegmatite
Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip
Degrees
Approx.
Strike
Bearing
Degrees
JOINTS
Tunnel N 86°33'W
COMMONWEALTH OF MASSACHUETTS
MET. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 630+00 TO 640+00
20 10 0 20 40 FT.

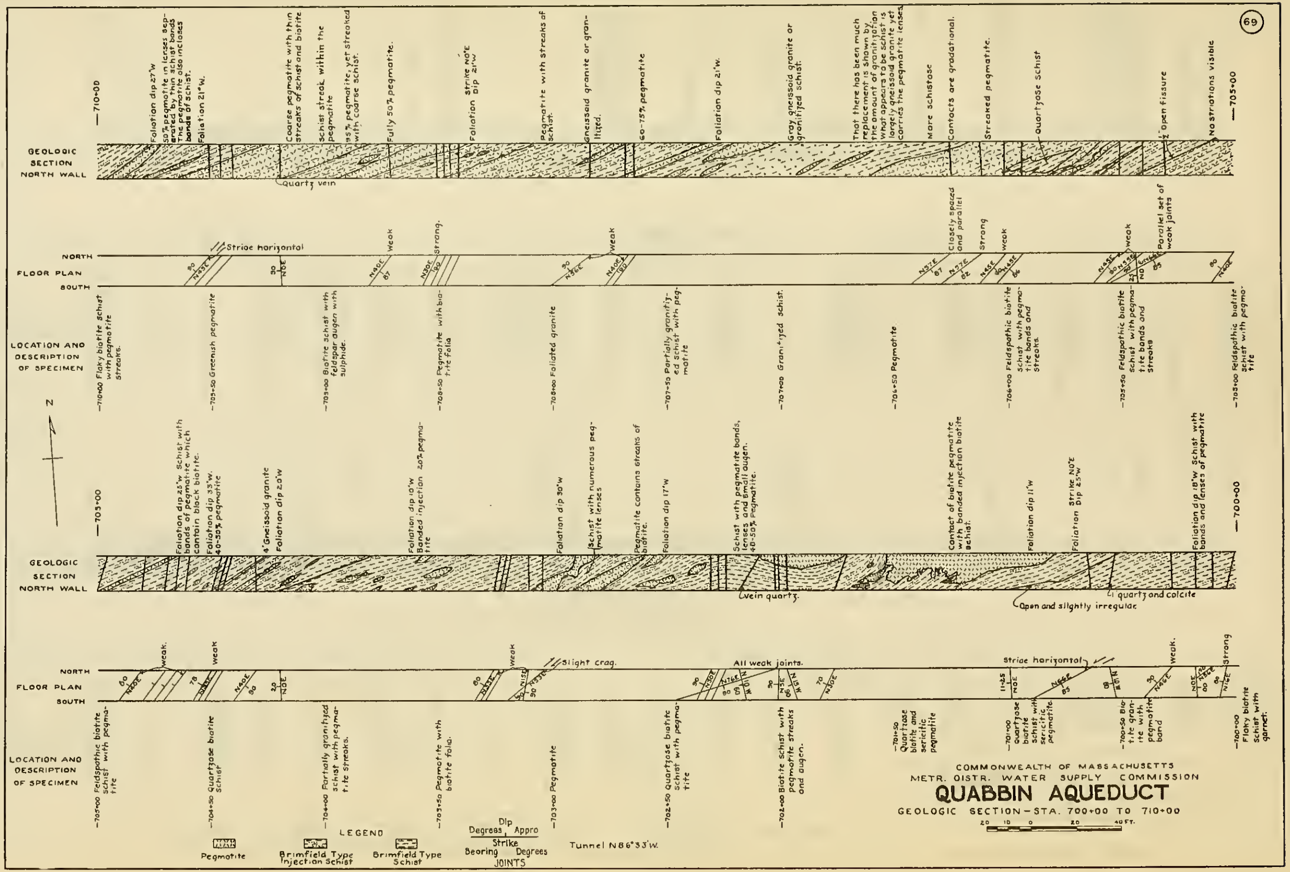

63
GEOLOGIC SECTION NORTH WALL
650+00
Pegmatite contains some schist.
Foliation dip 13°W
Massive gneissoid granite.
Foliation Strike N85°W.
Foliation dip 14°E
50% pegmatite.
Pegmatitic granite bands.
80% schist
Foliation Str. N76°E Dip 21°S (in section 12°E)
Schist with pegmatite intimately injected. Rock tends to be blocky
Foliation Str. N64°W Dip 53°W
645+00
Weak joints in the massive granite which do not continue in the schist.
8-12" extreme crushing
NORTH
FLOOR PLAN
SOUTH
Horizontal striae, south wall N.E.
LOCATION AND DESCRIPTION OF SPECIMEN
650+00 Greenish pegmatite with sulphide surfaces.
649+75 Chloritic garnetiferous pegmatite with sulphide surfaces.
649+50 Sheared chloritic pegmatite.
649+25 Flaky chloritic biotite schist
649+00 Garnetiferous biotite schist with pegmatite augen
648+75 Chloritic biotite schist.
648+50 Chloritic gneissoid biotite granite with sulphide.
648+25 Flaky chloritic biotite schist with chloritic pegmatite.
648+00 Granular pegmatite quartz with sulphide
647+75 Gneissoid biotite granite
647+50 Granitized schist with sulphide surfaces
647+25 Chloritic shear rock
647+00 Flaky chloritic biotite schist with sulphide
646+75 Biotite schist with chloritic pegmatite
646+50 Flaky chloritic schist with sulphide surfaces
646+25 Biotite schist with chloritic pegmatite and sulphide
646+00 Chloritic garnetiferous biotite schist
645+75 Coarse flaky biotite schist.
645+50 Sheared chloritic pegmatite
645+25 Sheared pegmatite
645+00 Sheared chloritic granite.
N
645+00
Massive quartz biotite schist with very little pegmatite.
Rock is blocky.
2" shear zone.
A bed of gneissoid granite, sill-like but probably due to replacement.
Many pegmatite lenses both large and small.
Rock is blocky.
50-75% pegmatite Schist tends to be granitized
Lenses of pegmatite and highly injected schist.
Foliation Str. N12°E Dip 15°E
Foliation nearly flat.
Abundant pegmatite with schist
Schist banded with pegmatite and considerably granitized.
Sill of white granitic pegmatite
640+00
6" Shear
6-12" Crushing Horizontal striae, west wall north
Striae parallel dip.
Two sets of striae, one parallels dip and appears later than striae dipping at right angles and S.E.
Slight streaking little biotite
NORTH
FLOOR PLAN
SOUTH
coarse calcite.
LOCATION AND DESCRIPTION OF SPECIMEN
645+00 Sheared chloritic granite
644+75 Garnetiferous biotite schist.
644+50 Garnetiferous biotite schist with pegmatite
644+00 Flaky chloritic biotite schist with sulphide.
643+75 Sheared chloritic pegmatite
643+50 Garnetiferous biotite schist with chloritic
643+25 Biotite schist with pegmatite and sulphide.
643+00 Flaky biotite schist with chloritic
642+75 Biotite schist with chloritic and sulphide.
642+50 Pegmatite biotite granite
642+25 Garnetiferous feldspathic biotite schist with pegmatite
642+00 Granitized schist with pegmatite
641+75 Partially granitized schist with pegmatite augen
641+50 Biotite schist with pegmatite
641+25 Gneissoid biotite granite.
641+00 White pegmatite
640+75 Biotite schist with pegmatite
640+50 Granitized schist
640+25 Greenish pegmatite
640+00 Sheared granitized schist with sulphide.
LEGEND
Pegmatite
Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel N86°33'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 640+00 TO 650+00
20 10 0 20 40 FT.

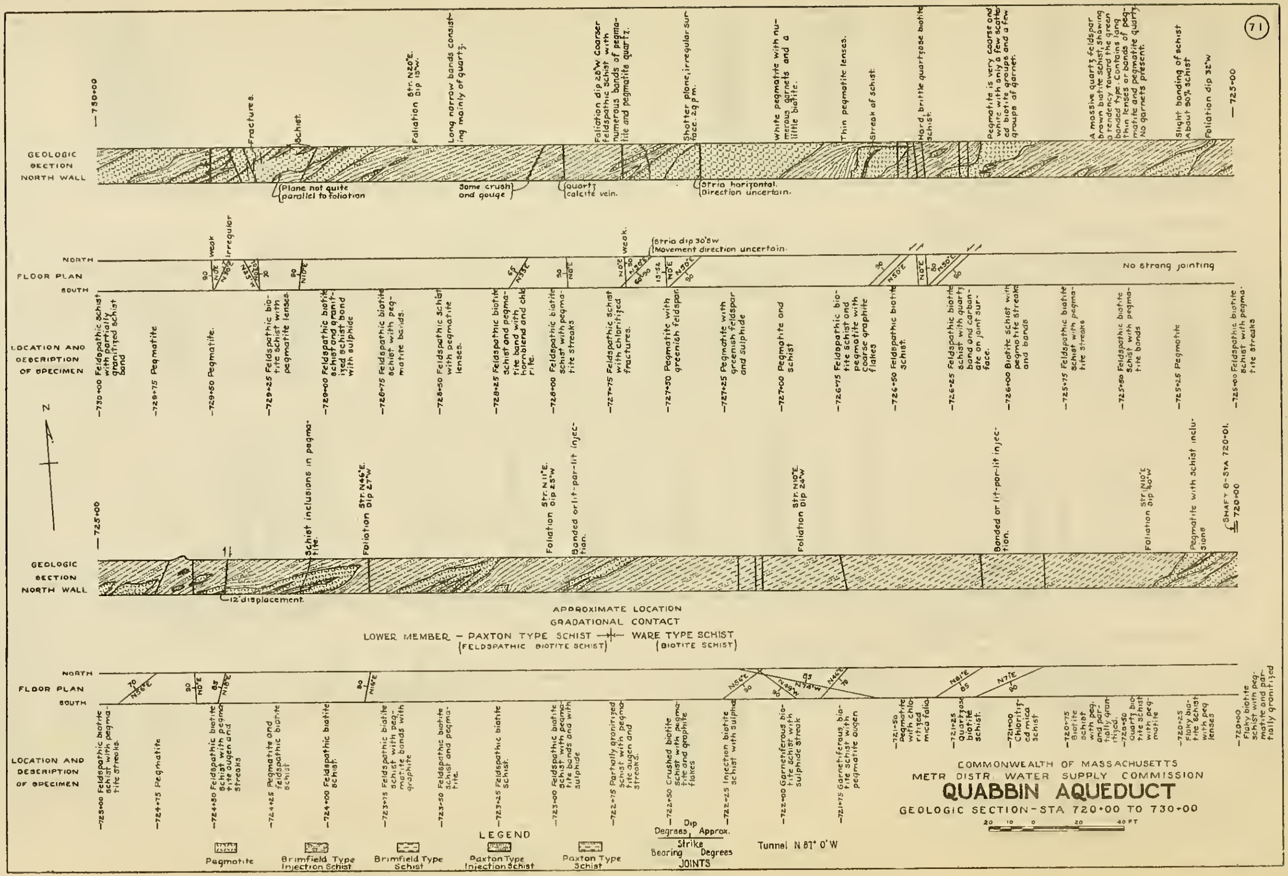

GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
—660+00
—655+00
—650+00
Gneissoid granite
Foliation of granite nearly flat.
Schist of Brimfield type.
Highly injected schist.
Foliation dip 8°E.
Foliation dip 22°E.
Numerous pegmatite lenses and bands.
Foliation nearly flat.
Vertical striae, carbonate and sulphide
Vertical striae, quartz
Horizontal striae, East wall South.
—660+00 Granite.
—659+00 Granite.
—658+00 Granite
—657+00 Granite.
—656+00 Granite
—655+00 Pegmatite
Schist is badly shattered. Linear parallelism N50°E
Granitized schist.
Foliation 10°E.
Foliation nearly flat.
Granite.
Foliation dip 10°W
Banded injection. Foliation 22°E.
Carries sulphide.
Strike parallel dip
—657+00
—654+00 Quartz biotite schist and pegmatite.
—653+00 Granitized schist
—652+00 Flaky biotite schist and pegmatite.
—651+00 Graphitic flaky biotite schist with pegmatite.
—650+00 Pegmatite with sulphide
LEGEND
Pegmatite
Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees, Approx.
Strike
Bearing Degrees
JOINTS
Tunnel N86°33'W.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 650+00 TO 660+00
20 10 0 20 40 FT.



66
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 670+00 TO 680+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
680+00
675+00
670+00
Calcite
Striae parallel dip(?).
12" Crush zone. Also crushing along pegmatite margins
Foliation dip 12°W
Foliation 21°W
Foliation dip 11°W
Schist more quartzose.
Foliation dip 35°W
Foliation dip 15°W 40% pegmatite
Linear parallelism N41°E
Numerous small bands and lenses of pegmatite
Crush zone parallel to foliation. Leakage 40 g.p.m. Foliation dip 15°W. Schist with pegmatite lenses.
// Striae dip 30°N.
–680+00 Flaky biotite schist and pegmatite with graphite flakes.
–679+00 Pegmatite with garnet and flaky biotite schist
–678+00 Biotite schist with pegmatite
–677+00 Pegmatite
–676+00 Flaky biotite schist with pegmatite streaks and augen.
–675+00 Pegmatite and partially granitized schist.
Highly injected schist
Banded injection.
Foliation Str N6°E dip 23°W
Biotite schist with bands and streaks of pegmatite
Streaks of schist in pegmatite.
2"-6" bands of pegmatite parallel to foliation.
Layers of more quartzose schist Foliation Str N6°E Dip 27°W
Foliation dip 6°W
Pegmatite with numerous schist bands.
About 85% pegmatite
Foliation 25°W
Foliation flat Pegmatite mass.
Structure of pegmatite reflects foliation of schist. Foliation dip 26°W.
Some injection bands are of quartz.
–675+00 Pegmatite and partially granitized schist
–674+00 Flaky biotite schist with sulphide
–673+00 Pegmatite
–672+00 Biotite schist with pegmatite streaks.
–671+00 Pegmatite and feldspathic biotite schist
–670+00 Coarse biotite schist.
N
LEGEND
Pegmatite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx. Strike Bearing Degrees JOINTS
Tunnel N86°33'W.

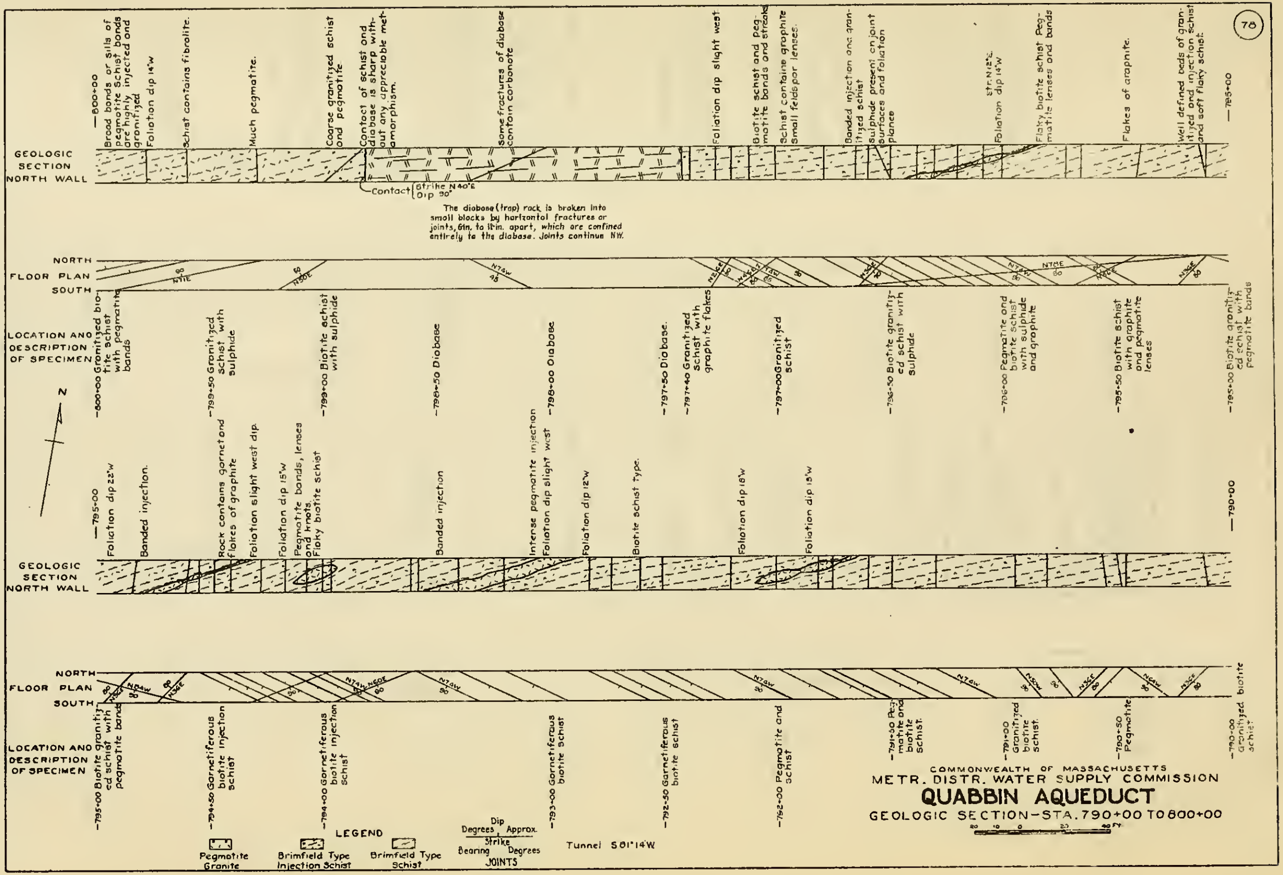

67
GEOLOGIC SECTION NORTH WALL
690+00
Finely laminated 2' diopside band
Foliation Strike N11°E Dip 23°W
Foliation dip 13°W
Foliation flat
Finely laminated diopside layer
Schist bands in pegmatite
Foliation dip 16°W
Foliation dip 40°W
Foliation dip 40°W
Foliation dip 35°W
Schist and pegmatite in normal contact
Strong shear
Foliation dip 23°W
Pegmatite contact str N0°E
Foliation cut off by pegmatite
50% pegmatite
Foliation dip 27°W
685+00
NORTH
FLOOR PLAN
SOUTH
Strong
Strike dip 23°N
Strong
LOCATION AND DESCRIPTION OF SPECIMEN
690+00 Biotite schist with pegmatite streaks
689+50 Biotite schist with pegmatite streaks
689+00 Carbonate rock with greenish diopside bands.
688+50 Pegmatite with sulphide and scattered hornblende
688+00 Biotite streaked pegmatite with schist remnant
687+00 quartzose biotite schist
687+00 Flaky biotite schist with pegmatite dungen and streaks
686+00 Pegmatite with biotite folia
685+00 Pegmatite with garnet
N
685+00
Foliation dip 19°W
Foliation Strike N16°E Dip 28°W
Foliation dip 18°W
Laminated schist Some green banding
Foliation 12°W
Black biotite schist close to the pegmatite
Strongly banded green diopside layers May represent original limestone
Granitized schist with abundant garnets.
Pegmatite with bands of schist
Schist with numerous lenses and bands of pegmatite
680+00
GEOLOGIC SECTION NORTH WALL
Crush
Crumpling of Schist
Lowangle slip Str N11°E, Dip 11°E
Calcite coated
Striae dip 30°N
Some diopside in brown biotite schist. Strong quartz pegmatite banding
Biotite pegmatite
NORTH
FLOOR PLAN
SOUTH
Fracture zone
LOCATION AND DESCRIPTION OF SPECIMEN
685+00 Pegmatite with garnet
684+00 Biotite schist with bands and streaks of pegmatite
683+00 Feldspathic quartz biotite schist and pegmatite bands with graphite flakes.
682+00 Granite with sulphide
681+00 Pegmatite
680+00 Flaky biotite schist and pegmatite with graphite flakes.
LEGEND
Pegmatite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx
Strike Bearing Degrees
JOINTS
Tunnel N86°33'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA 680+00 TO 690+00
20 10 0 20 40 FT.

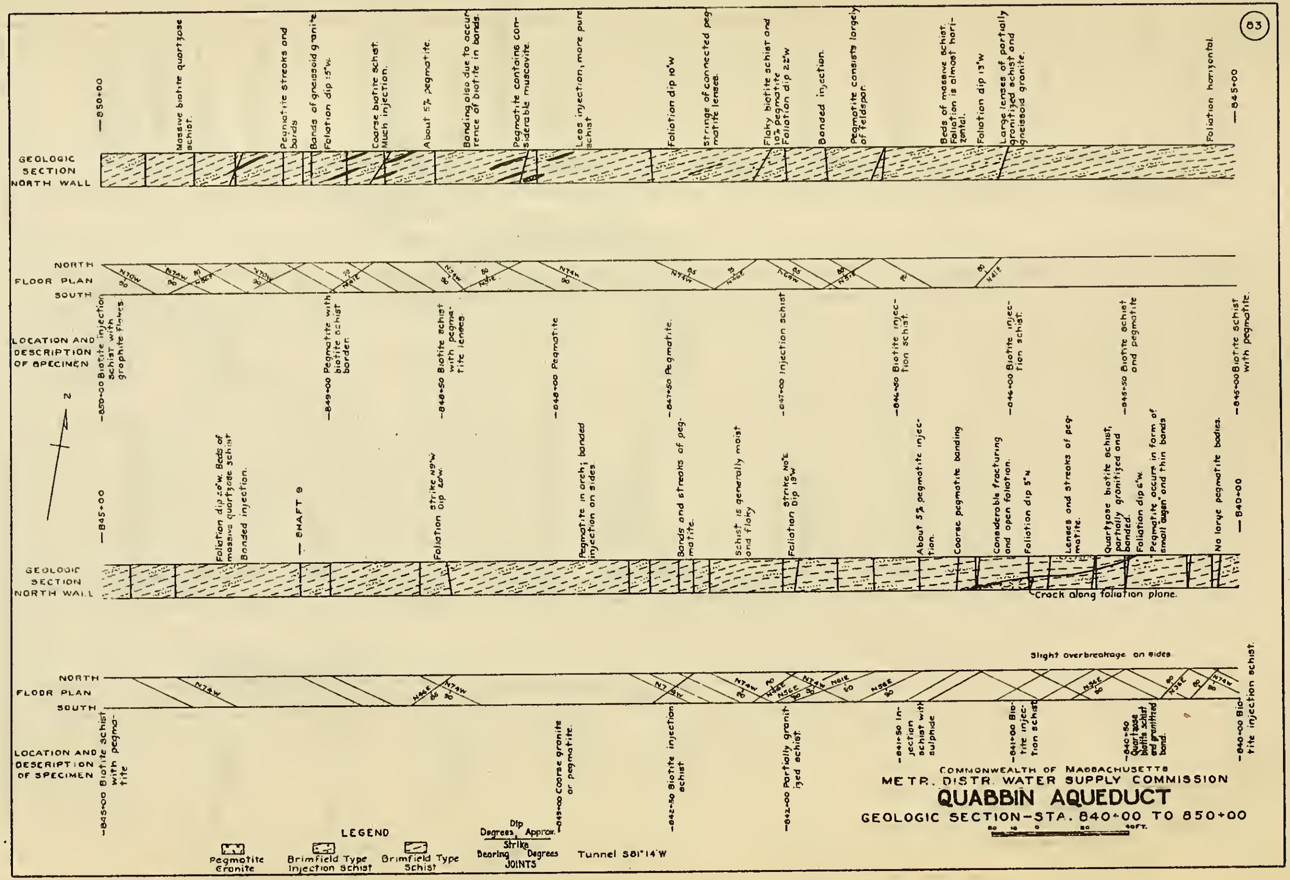

69
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION – STA. 700+00 TO 710+00
20 10 0 20 40 FT.
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
710+00
705+00
700+00
Foliation dip 27°W
50% pegmatite in lenses separated by thin schist bands. The pegmatite also incloses bands of schist.
Foliation 21°W.
Quartz vein
Coarse pegmatite with thin streaks of schist and biotite
Schist streak within the pegmatite
95% pegmatite, yet streaked with coarse schist.
Fully 50% pegmatite.
Foliation Strike N0°E Dip 21°W
Pegmatite with streaks of schist.
Gneissoid granite or granitized.
60-75% pegmatite
Foliation dip 21°W.
Gray gneissoid granite or granitized schist.
That there has been much replacement is shown by the amount of granitization. What appears to be schist is largely gneissoid granite yet carries the pegmatite lenses.
More schistose
Contacts are gradational.
Streaked pegmatite.
Quartzose schist
¼" open fissure
No striations visible
Striae horizontal
Weak
Strong.
Closely spaced and parallel
Strong
Parallel set of weak joints
–710+00 Flaky biotite schist with pegmatite streaks.
–709+50 Greenish pegmatite
–709+00 Biotite schist with feldspar augen with sulphide.
–708+50 Pegmatite with biotite folia
–708+00 Foliated granite
–707+50 Partially granitized schist with pegmatite
–707+00 Granitized schist.
–706+50 Pegmatite
–706+00 Feldspathic biotite schist with pegmatite bands and streaks.
–705+50 Feldspathic biotite schist with pegmatite bands and streaks
–705+00 Feldspathic biotite schist with pegmatite
Foliation dip 25°W Schist with bands of pegmatite which contain black biotite.
Foliation dip 33°W. 40-30% pegmatite
4' Gneissoid granite
Foliation dip 20°W
Foliation dip 10°W Banded injection 20% pegmatite
Foliation dip 30°W
Schist with numerous pegmatite lenses
Pegmatite contains streaks of biotite.
Foliation dip 17°W
Schist with pegmatite bands, lenses and small augen. 40-50% Pegmatite.
Vein quartz.
Contact of biotite pegmatite with banded injection biotite schist.
Foliation dip 11°W
Foliation Strike N0°E Dip 25°W
Foliation dip 18°W Schist with bands and lenses of pegmatite
Open and slightly irregular
¼" quartz and calcite
Slight crag.
All weak joints.
Striae horizontal
–705+00 Feldspathic biotite schist with pegmatite
–704+50 Quartzose biotite schist
–704+00 Partially granitized schist with pegmatite streaks.
–703+50 Pegmatite with biotite folia.
–703+00 Pegmatite
–702+50 Quartzose biotite schist with pegmatite
–702+00 Biotite schist with pegmatite streaks and augen.
–701+50 Quartzose biotite and sericitic pegmatite
–701+00 Quartzose biotite schist with sericitic pegmatite
–700+50 Biotite granite with pegmatite band
–700+00 Flaky biotite schist with garnet.
LEGEND
Pegmatite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Appro
Strike
Bearing Degrees
JOINTS
Tunnel N86°33'W.

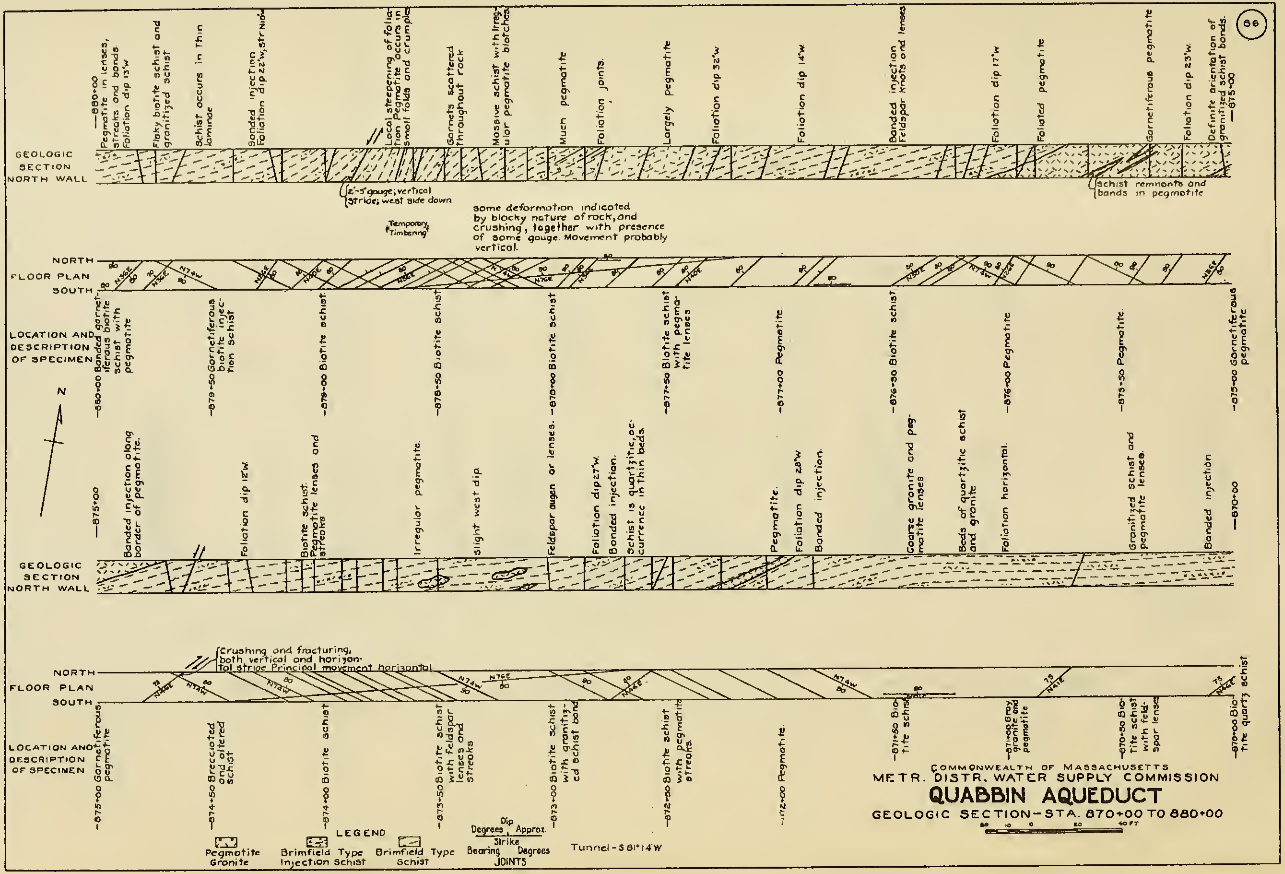


71
COMMONWEALTH OF MASSACHUSETTS
METR DISTR WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA 720+00 TO 730+00
Tunnel N 87° 0' W
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
No strong jointing
APPROXIMATE LOCATION GRADATIONAL CONTACT
LOWER MEMBER - PAXTON TYPE SCHIST (FELDSPATHIC BIOTITE SCHIST)
WARE TYPE SCHIST (BIOTITE SCHIST)
12" displacement.
SHAFT 8 - STA 720+01.
LEGEND
Pegmatite
Brimfield Type Injection Schist
Brimfield Type Schist
Paxton Type Injection Schist
Paxton Type Schist
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS

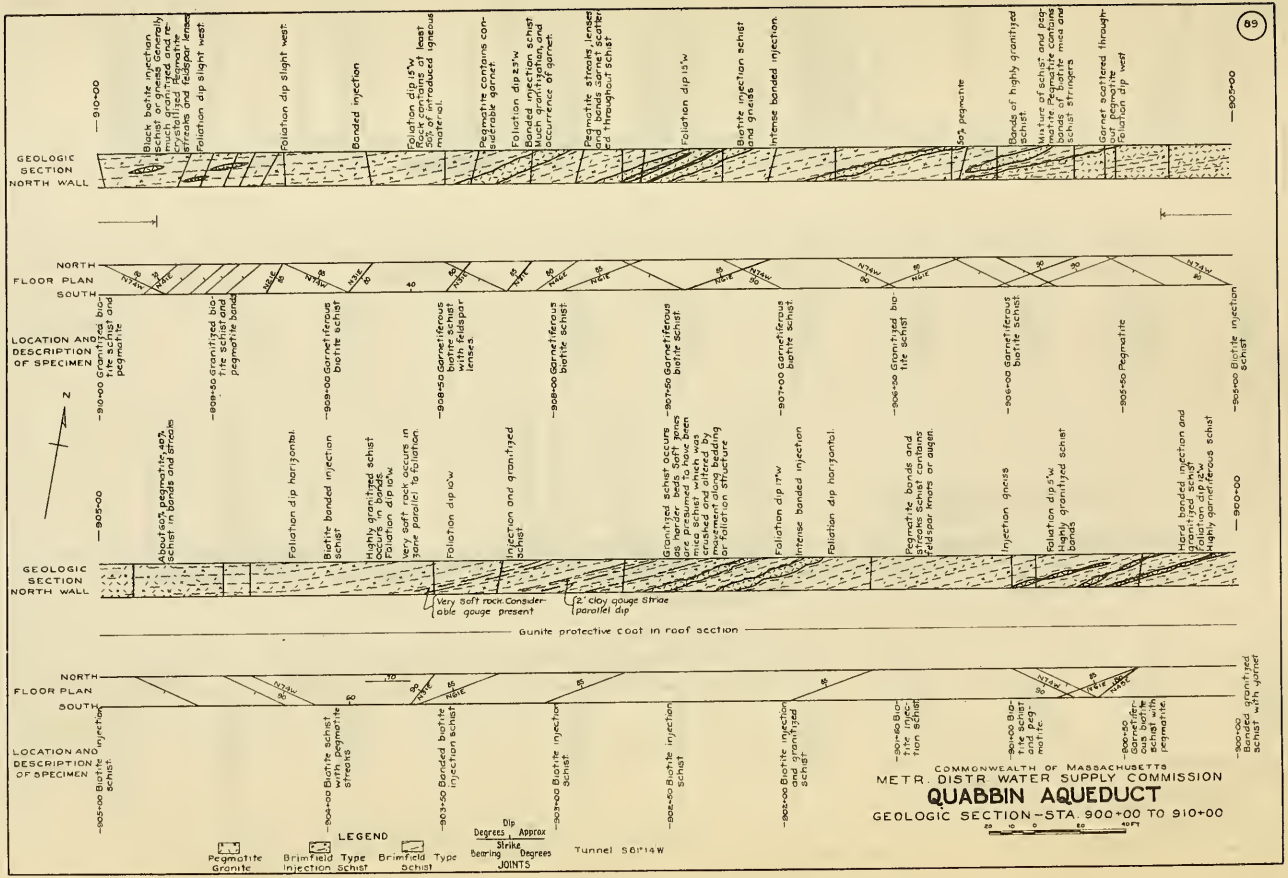
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION–STA 730+00 TO 740+00
LEGEND
Pegmatite
Brimfield Type Schist
Brimfield Type Injection Schist
Paxton Type Injection Schist
Paxton Type Schist
Dip Degrees
Strike Approx. Bearing Degrees
JOINTS
Tunnel N 81° W
UPPER MEMBER – PAXTON TYPE SCHIST (FELDSPATHIC BIOTITE SCHIST) + PAXTON TYPE SCHIST – MIDDLE MEMBER
APPROXIMATE LOCATION GRADATIONAL CONTACT
MIDDLE MEMBER – PAXTON TYPE SCHIST (GARNETIFEROUS BIOTITE SCHIST) + PAXTON TYPE SCHIST – LOWER MEMBER (FELDSPATHIC BIOTITE SCHIST)
GEOLOGIC SECTION
FLOOR PLAN
LOCATION AND DESCRIPTION OF SPECIMEN
NORTH
SOUTH
NORTH WALL


78
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
800+00
Broad bands or sills of pegmatite schist bands are highly injected and granitized
Foliation dip 14°W
Schist contains fibrolite.
Much pegmatite.
Coarse granitized schist and pegmatite.
Contact of schist and diabase is sharp without any appreciable metamorphism.
Contact
Strike N40°E
Dip 90°
The diabase (trap) rock is broken into small blocks by horizontal fractures or joints, 6in. to 1ft. apart, which are confined entirely to the diabase. Joints continue NW.
Some fractures of diabase contain carbonate
Foliation dip slight west
Biotite schist and pegmatite bands and streaks
Schist contains graphite Small feldspar lenses.
Banded injection and granitized schist
Sulphide present on joint surfaces and foliation planes
Str. N12°E
Foliation dip 14°W
Flaky biotite schist Pegmatite lenses and bands
Flakes of graphite.
Well defined beds of granitized and injection schist and soft flaky schist.
795+00
800+00 Granitized biotite schist with pegmatite bands
799+50 Granitized schist with sulphide
799+00 Biotite schist with sulphide
798+50 Diabase
798+00 Diabase
797+50 Diabase.
797+40 Granitized schist with graphite flakes
797+00 Granitized schist
796+50 Biotite granitized schist with sulphide
796+00 Pegmatite and biotite schist with sulphide and graphite
795+50 Biotite schist with graphite and pegmatite lenses
795+00 Biotite granitized schist with pegmatite bands
Foliation dip 22°W
Banded injection.
Rock contains garnet and flakes of graphite
Foliation slight west dip.
Foliation dip 15°W
Pegmatite bands, lenses and knots.
Flaky biotite schist
Banded injection
Intense pegmatite injection
Foliation dip slight west
Foliation dip 12°W
Biotite schist type.
Foliation dip 18°W
Foliation dip 15°W
790+00
795+00 Biotite granitized schist with pegmatite bands
794+50 Garnetiferous biotite injection schist
794+00 Garnetiferous biotite injection schist
793+00 Garnetiferous biotite schist
792+50 Garnetiferous biotite schist
792+00 Pegmatite and schist
791+50 Pegmatite and biotite schist.
791+00 Granitized biotite schist.
790+50 Pegmatite
790+00 Granitized biotite schist
N
LEGEND
Pegmatite Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx.
Strike
Bearing Degrees
JOINTS
Tunnel S81°14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION-STA. 790+00 TO 800+00


83
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION–STA. 840+00 TO 850+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
SHAFT 9
Crack along foliation plane.
Slight overbreakage on sides
LEGEND
Pegmatite Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees, Approx.
Strike Bearing Degrees
JOINTS
Tunnel S81°14'W
850+00
845+00
840+00
Massive biotite quartzose schist.
Pegmatite streaks and bands
Bands of gneissoid granite
Foliation dip 15°W.
Coarse biotite schist. Much injection.
About 5% pegmatite.
Banding also due to occurrence of biotite in bands.
Pegmatite contains considerable muscovite.
Less injection, more pure schist
Foliation dip 10°W
Stringe of connected pegmatite lenses.
Flaky biotite schist and 10% pegmatite Foliation dip 22°W
Banded injection.
Pegmatite consists largely of feldspar.
Beds of massive schist. Foliation is almost horizontal.
Foliation dip 13°W
Large lenses of partially granitized schist and gneissoid granite.
Foliation horizontal.
850+00 Biotite injection schist with graphite flakes.
849+00 Pegmatite with biotite schist border.
848+50 Biotite schist with pegmatite lenses.
848+00 Pegmatite
847+50 Pegmatite.
847+00 Injection schist
846+50 Biotite injection schist.
846+00 Biotite injection schist.
845+50 Biotite schist and pegmatite
845+00 Biotite schist with pegmatite.
Foliation dip 20°W. Beds of massive quartzose schist
Banded injection.
Foliation strike N9°W Dip 20°W
Pegmatite in arch; banded injection on sides
Bands and streaks of pegmatite.
Schist is generally moist and flaky
Foliation strike N0°E Dip 19°W
About 5% pegmatite injection.
Coarse pegmatite banding
Considerable fracturing and open foliation.
Foliation dip 5°W
Lenses and streaks of pegmatite.
Quartzose biotite schist, partially granitized and banded.
Foliation dip 6°W.
Pegmatite occurs in form of small augen and thin bands
No large pegmatite bodies.
845+00 Biotite schist with pegmatite
843+00 Coarse granite or pegmatite.
842+50 Biotite injection schist
842+00 Partially granitized schist.
841+50 Injection schist with sulphide
841+00 Biotite injection schist.
840+50 Quartzose biotite schist and granitized band.
840+00 Biotite injection schist.


GEOLOGIC SECTION NORTH WALL
—880+00
Pegmatite in lenses, streaks and bands Foliation dip 13°W
Flaky biotite schist and granitized schist
Schist occurs in thin laminae
Banded injection Foliation dip 22°W, str N10W
Local steepening of foliation Pegmatite occurs in small folds and crumples
Garnets scattered throughout rock
Massive schist with irregular pegmatite blotches
Much pegmatite
Foliation joints.
Largely pegmatite
Foliation dip 32°W
Foliation dip 14°W
Banded injection Feldspar knots and lenses
Foliation dip 17°W
Foliated pegmatite
Garnetiferous pegmatite
Foliation dip 23°W
Definite orientation of granitized schist bands.
—875+00
2"-3" gouge; vertical Stride; west side down
Temporary Timbering
Schist remnants and bands in pegmatite
Some deformation indicated by blocky nature of rock, and crushing, together with presence of some gouge. Movement probably vertical.
NORTH FLOOR PLAN SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—880+00 Banded garnetiferous biotite schist with pegmatite
—879+50 Garnetiferous biotite injection schist
—879+00 Biotite schist
—878+50 Biotite schist
—878+00 Biotite schist
—877+50 Biotite schist with pegmatite lenses
—877+00 Pegmatite
—876+50 Biotite schist
—876+00 Pegmatite
—875+50 Pegmatite.
—875+00 Garnetiferous pegmatite
N
GEOLOGIC SECTION NORTH WALL
—875+00
Banded injection along border of pegmatite.
Foliation dip 12°W.
Biotite schist. Pegmatite lenses and streaks
Irregular pegmatite.
Slight west dip.
Feldspar augen or lenses.
Foliation dip 27°W.
Banded injection.
Schist is quartzitic, occurrence in thin beds.
Pegmatite.
Foliation dip 28°W
Banded injection.
Coarse granite and pegmatite lenses
Beds of quartzitic schist and granite
Foliation horizontal.
Granitized schist and pegmatite lenses.
Banded injection
—870+00
Crushing and fracturing, both vertical and horizontal striae Principal movement horizontal
NORTH FLOOR PLAN SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—875+00 Garnetiferous pegmatite
—874+50 Brecciated and altered schist
—874+00 Biotite schist
—873+50 Biotite schist with feldspar lenses and streaks
—873+00 Biotite schist with granitized schist band
—872+50 Biotite schist with pegmatite streaks
—872+00 Pegmatite.
—871+50 Biotite schist
—871+00 Gray granite and pegmatite
—870+50 Biotite schist with feldspar lenses
—870+00 Biotite quartz schist
LEGEND
Pegmatite Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx. Strike Bearing Degrees JOINTS
Tunnel - S 81°14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 870+00 TO 880+00
40 FT

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 890+00 TO 900+00
LEGEND
Pegmatite Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees
Strike Approx. Degrees
Bearing
JOINTS
Tunnel - S 81°14' W
Gunite protective coat in roof section
GEOLOGIC SECTION NORTH WALL
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
Joints stop abruptly at contact but there has been no movement
Typical block biotite injection schist. Granite occurs in lenses and bands orientated parallel to the foliation. Foliation dip 20°W.
Light injection gneiss.
Foliation dip 20°W
Gray foliated granite containing schist stringers and mica bands
Dull block closely knit biotite schist. Some injection bodies are of gray banded granite
Although the rock is a biotite schist it is somewhat different from the true Brimfield type in that it looks black and is considerably more garnetiferous
Foliation dip 10°W
Dark massive schist with few pegmatite streaks and bands
Bonded injection
Foliation dip 10°W.
Much pegmatite and banded injection.
Bonded injection biotite schist.
Bonded injection biotite schist and gneiss
Foliation dip 10°W
Pegmatite knots and lenses
Foliation dip slight west
Bonded injection biotite schist
Foliation dip 12°W
Pegmatite and granitized schist bands
Foliation dip 10°W
Block biotite schist, in places strongly garnetiferous.
Foliation dip 20°W
Bonded injection biotite schist
Foliation dip slight west
Pegmatite and gneiss
Foliation dip 15°W
The rock is highly garnetiferous
Bonded injection biotite schist with garnet
Bonded granitized biotite schist with garnet
Bonded injection biotite schist.
Granitized biotite schist with garnet
Bonded injection biotite schist.
Granitized biotite schist with garnet
Bonded injection biotite schist.
Bonded injection biotite schist.
Injection biotite gneiss
The rock is soft and scales easily
Strike N7°E
Foliation Dip 13°W
Granitized biotite schist.
Pegmatite and feldspar knots and lenses
Granitized biotite schist.
Granitized biotite schist.
Granite
Pegmatite and granitized schist
Granitized biotite schist with garnet
Granitized biotite schist.
Biotite quartzite
Granitized biotite schist.
Biotite gneiss or dark granite schist.
Granitized biotite schist.
Granitized biotite schist.
Granitized biotite schist with pegmatite bands
Granitized biotite schist.
Granitized biotite schist.
Granitized biotite schist.
Granitized biotite schist.
Granitized biotite schist.
Granitized biotite schist.
Granite


GEOLOGIC SECTION NORTH WALL
FLOOR PLAN NORTH SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
910+00
Black biotite injection schist or gneiss Generally much granitized and re-crystallized Pegmatite streaks and feldspar lenses
Foliation dip slight west.
Foliation dip slight west.
Banded injection
Foliation dip 15°W Rock contains at least 50% of introduced igneous material.
Pegmatite contains considerable garnet.
Foliation dip 23°W
Banded injection schist Much granitization, and occurrence of garnet.
Pegmatite streaks, lenses and bands Garnet scattered throughout schist
Foliation dip 15°W
Biotite injection schist and gneiss
Intense banded injection.
50% pegmatite
Bands of highly granitized schist.
Mixture of schist and pegmatite. Pegmatite contains bands of biotite mica and schist stringers
Garnet scattered throughout pegmatite Foliation dip west
905+00
910+00 Granitized biotite schist and pegmatite
909+50 Granitized biotite schist and pegmatite bands
909+00 Garnetiferous biotite schist
908+50 Garnetiferous biotite schist with feldspar lenses.
908+00 Garnetiferous biotite schist.
907+50 Garnetiferous biotite schist.
907+00 Garnetiferous biotite schist.
906+50 Granitized biotite schist
906+00 Garnetiferous biotite schist.
905+50 Pegmatite
905+00 Biotite injection schist
N
905+00
About 60% pegmatite, 40% schist in bands and streaks
Foliation dip horizontal.
Biotite banded injection schist
Highly granitized schist occurs in bands. Foliation dip 10°W
Very soft rock occurs in zone parallel to foliation.
Foliation dip 10°W
Injection and granitized schist.
Granitized schist occurs as harder beds Soft zones are presumed to have been mica schist which was crushed and altered by movement along bedding or foliation structure
Foliation dip 17°W
Intense banded injection
Foliation dip horizontal.
Pegmatite bands and streaks Schist contains feldspar knots or augen.
Injection gneiss
Foliation dip 5°W Highly granitized schist bands
Hard banded injection and granitized schist Foliation dip 12°W Highly garnetiferous schist
900+00
Very Soft rock. Considerable gouge present
2" clay gouge Striae parallel dip
Gunite protective coat in roof section
905+00 Biotite injection schist.
904+00 Biotite schist with pegmatite streaks
903+50 Banded biotite injection schist
903+00 Biotite injection schist.
902+50 Biotite injection schist
902+00 Biotite injection and granitized schist
901+50 Biotite injection schist
901+00 Biotite schist and pegmatite.
900+50 Garnetiferous biotite schist with pegmatite.
900+00 Banded granitized schist with garnet
LEGEND
Pegmatite Granite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx Strike Bearing Degrees JOINTS
Tunnel S61°14'W
N74W
N61E
N31E
N46E
N45E
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 900+00 TO 910+00
20 10 0 20 40 FT

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 910+00 TO 920+00
GEOLOGIC SECTION
NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
LEGEND
Pegmatite Granite
Brimfield Type Injection Schist
Brimfield Type Schist Type
Dip Degrees
Strike Bearing
Approx. Degrees
JOINTS
Tunnel 8&1-14 W
Gunite protective coat in roof
Largely gneiss with about equal amounts of schist and granite or pegmatite or introduced igneous material.
Schist portions occur within and surrounded by pegmatite.
Contains much garnet and bands of distinctly reddish color, probably from feldspar occurrence
Bolt-like bodies of pegmatite containing much schist
Bands of pegmatite and granite
Foliation dip 7W
Pegmatite bands and lenses
Coarse biotite schist or gneiss feldspar crystals scattered throughout rock
Foliation dip slight west
Bonded injection gneiss
Coarse pink feldspar in pegmatite
Foliation dip 12W
Largely coarse granite and gneiss containing schist bands and remnants
Biotite injection schist or gneiss. Pegmatite bands, stringers, and lenses
Foliation dip slight west
Biotite injection schist or gneiss. Pegmatite bands and stringers, feldspar knots and small lenses. Rock is similar to that in east tunnel—schist is
Foliation dip 15W, strike N.E.
Injection biotite schist or gneiss. Light granite occurs in lenticular bands.
Foliation dip 16W
Coarse granite injection gneiss
Finely banded gneiss. Garnets (?alum) scattered thru rock
Foliation dip horizontal
Lenticular pegmatite bands
Biotite schist or gneiss.
Foliation dip horizontal wide bands of pegmatite granite
Biotite schist or gneiss. Small lenses feldspar knots and
Foliation dip 13W
Much garnet scattered throughout pegmatite
Banded injection schist and gneiss
Foliation dip slight west
Bands of garnetiferous pegmatite which resulting in discontinuous lenses granite also occurs in this manner
Foliation dip 5W
Feldspar knots or 'eyes'
Foliation dip 5E
Foliation dip slight east
Biotite injection and granite
Foliation dip 5W
Banded schist and granite
Hard biotite gneiss some pink feldspar occurs
—920+00
—919+00
—918+00
—917+00
—916+00
—915+00
—914+00
—913+00
—912+00
—911+00
—910+00
—913-50 Pegmatite
—914-50 Garnetiferous biotite schist and aplite
—914-00 Garnetiferous granitized schist with garnet and pegmatite
—913-00 Garnetiferous granitized biotite schist
—913-50 Garnetiferous granitized biotite schist
—912-50 Garnetiferous granitized biotite schist
—912-00 Garnetiferous granitized biotite schist
—911-50 Garnetiferous biotite schist with feldspar gneiss
—911-00 Garnetiferous pegmatite
—910-50 Garnetiferous biotite schist and pegmatite
—919-00 Garnetiferous biotite schist and gneiss
—919-50 Garnetiferous biotite schist with pegmatite lenses
—918-50 Garnetiferous biotite schist
—918-00 Garnetiferous biotite schist with pegmatite lenses
—917-50 Biotite schist lenses
—917-00 Garnetiferous biotite injection schist
—916-50 Garnetiferous granitized schist
—916-00 Garnetiferous schist with feldspar lenses
—915-50 Garnetiferous granitized biotite schist
—915-00 Garnetiferous granitized biotite schist
—920-00 Garnetiferous granitized biotite schist
—919-50 Garnetiferous biotite schist
—918-50 Garnetiferous granitized biotite schist
—917-50 Garnetiferous biotite schist
—916-50 Garnetiferous granitized biotite schist
—915-50 Garnetiferous granitized biotite schist
—914-50 Garnetiferous biotite schist
—913-50 Garnetiferous biotite schist
—912-50 Garnetiferous biotite schist
—911-50 Garnetiferous biotite schist
—910-50 Garnetiferous biotite schist
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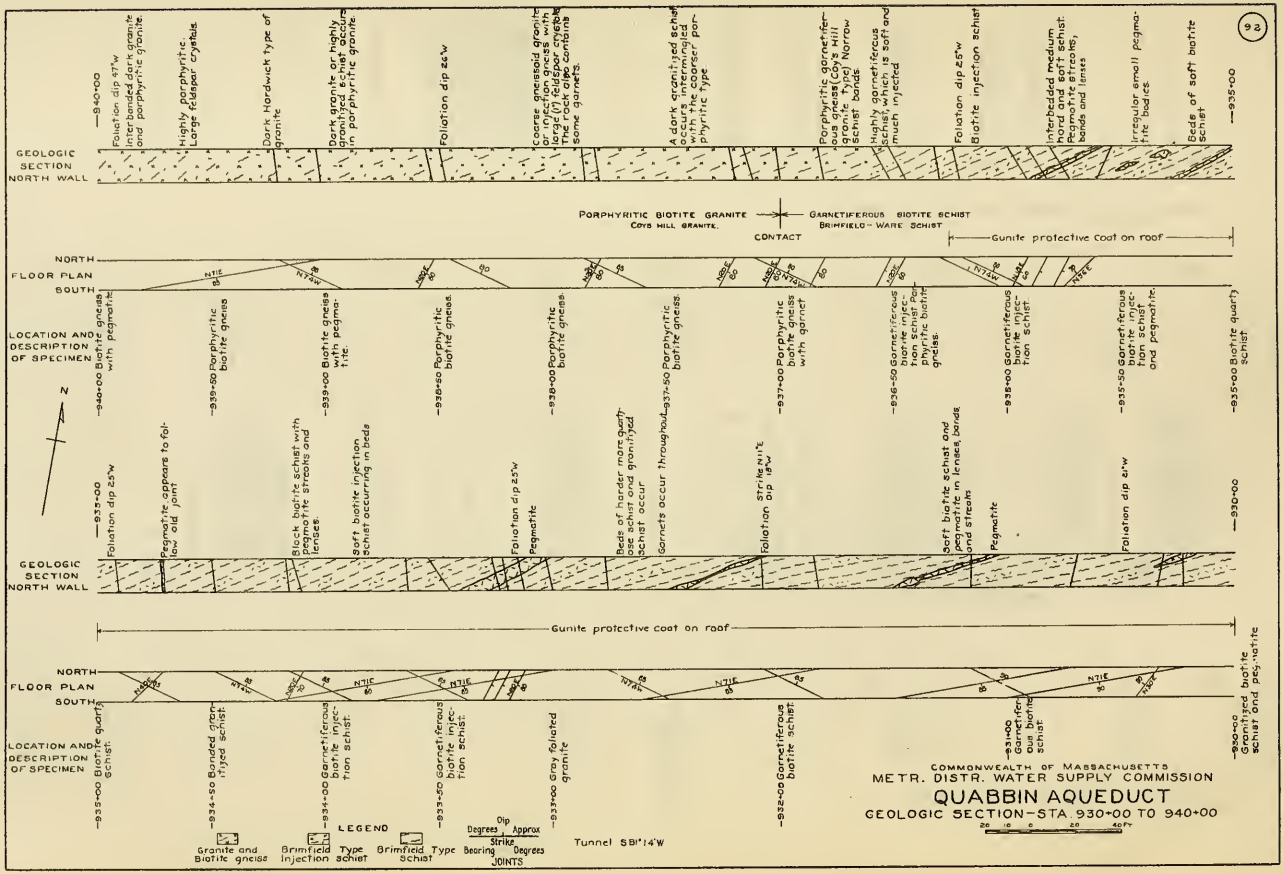
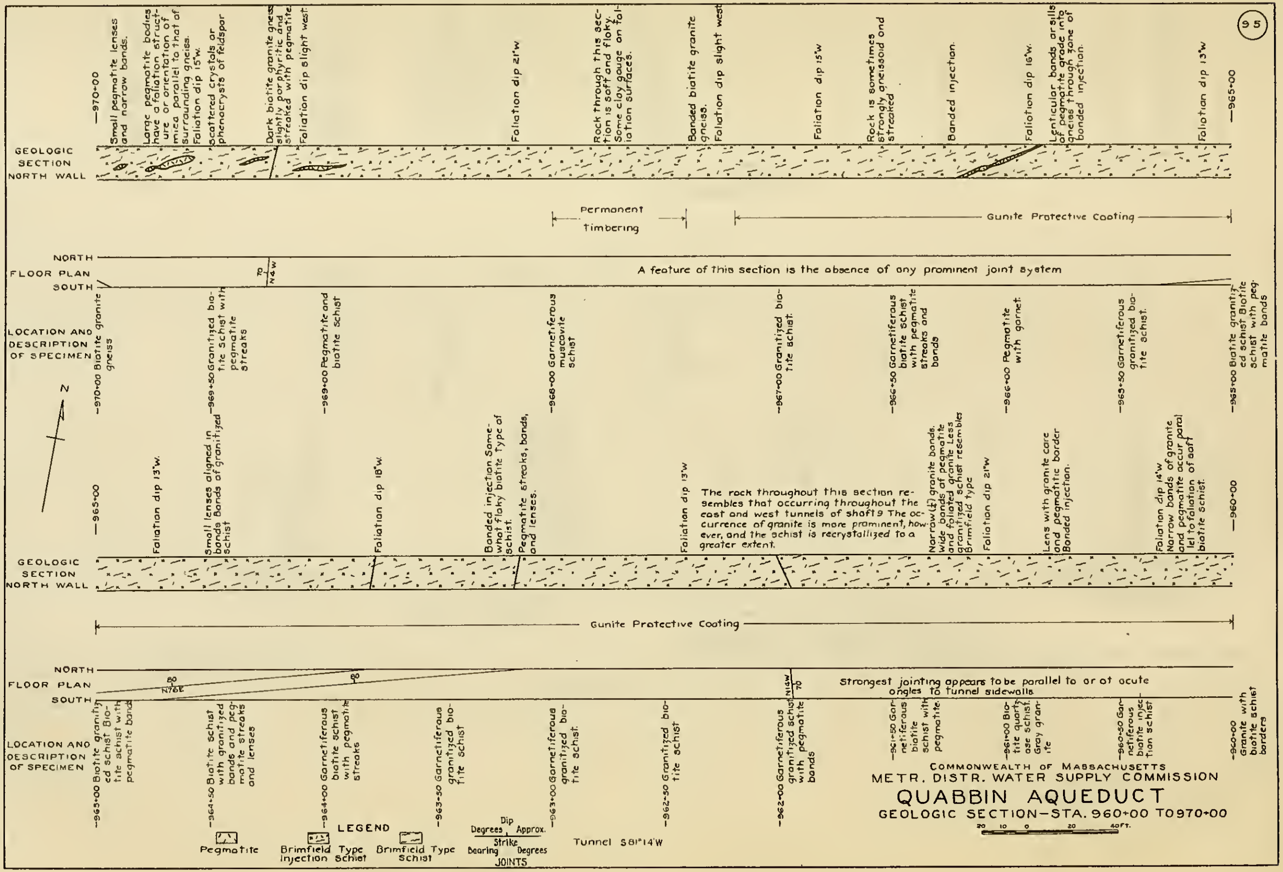
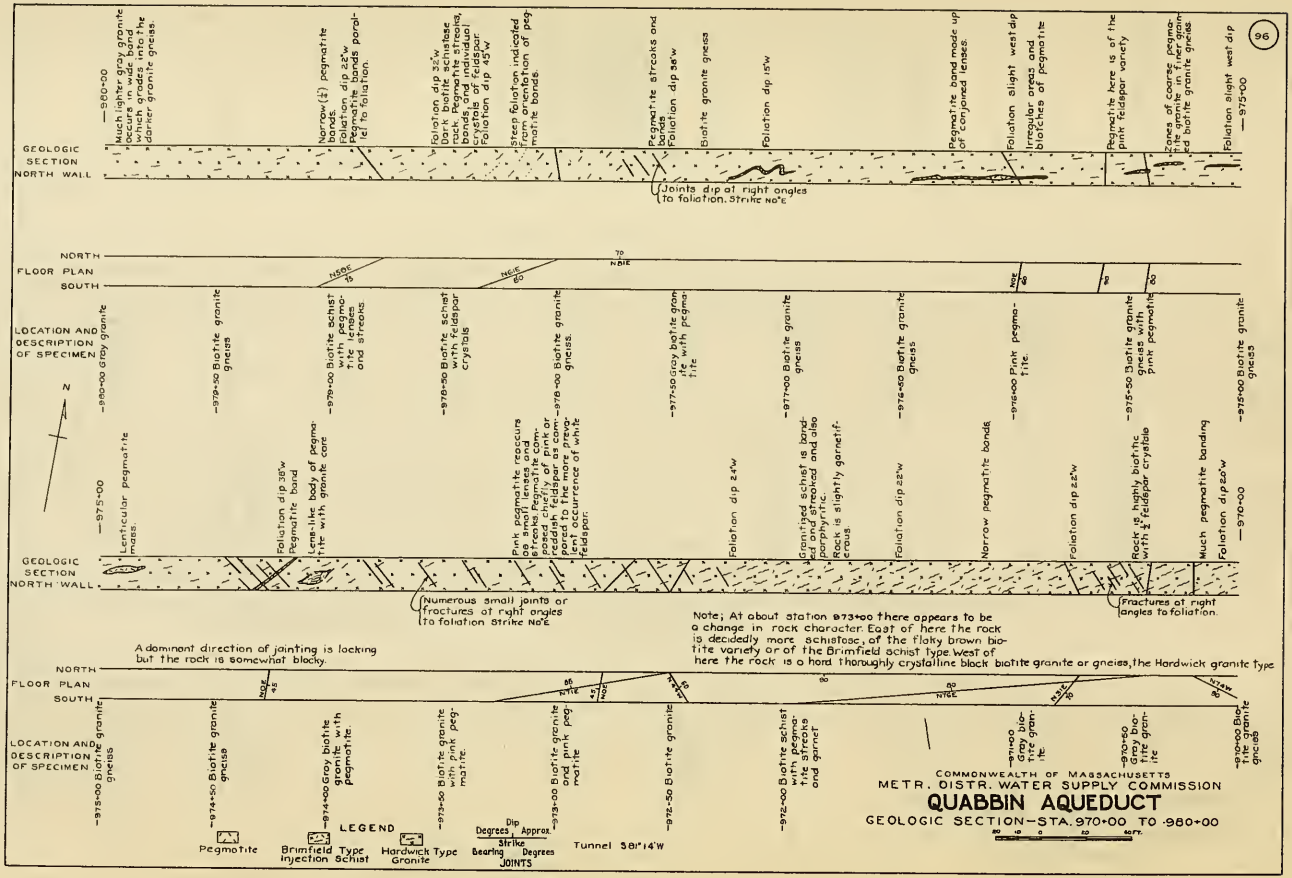
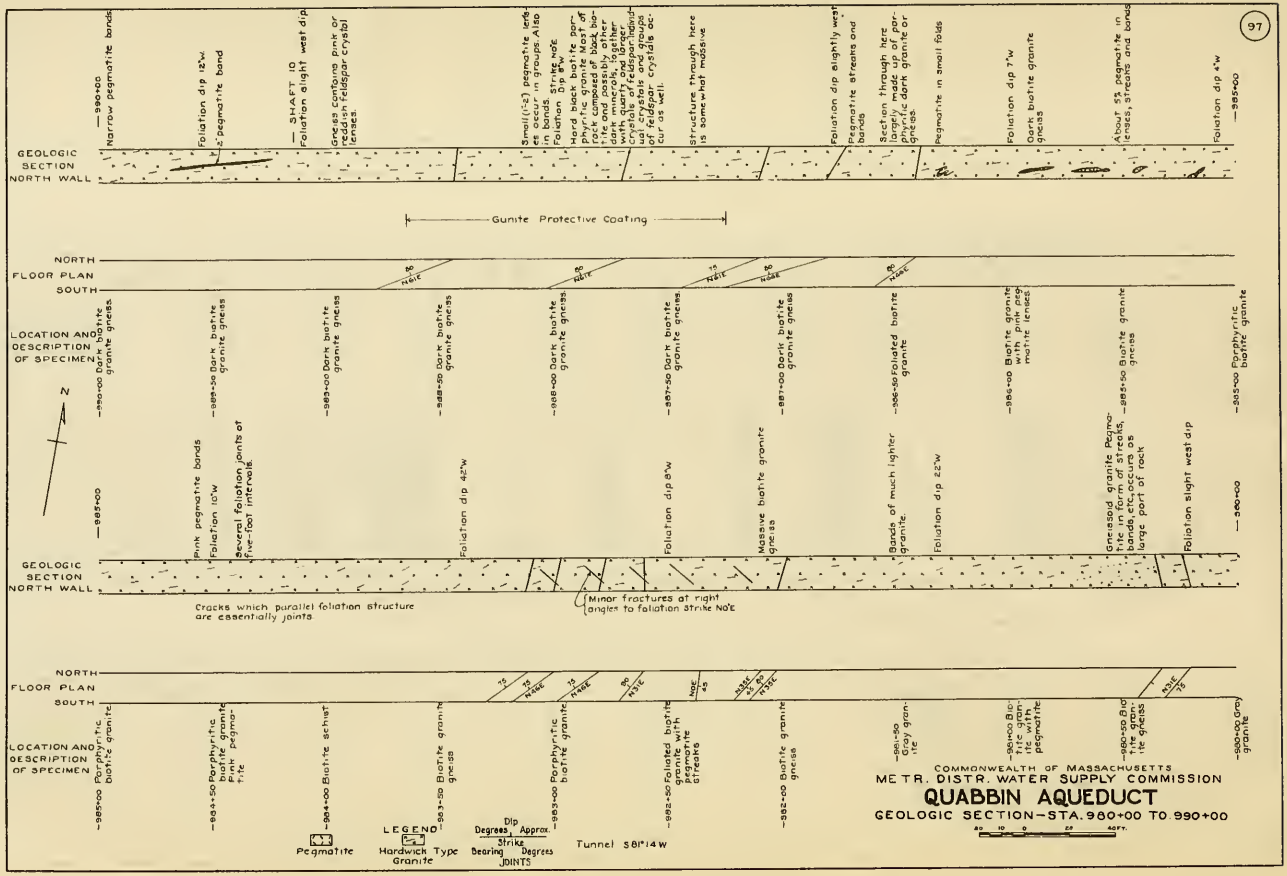
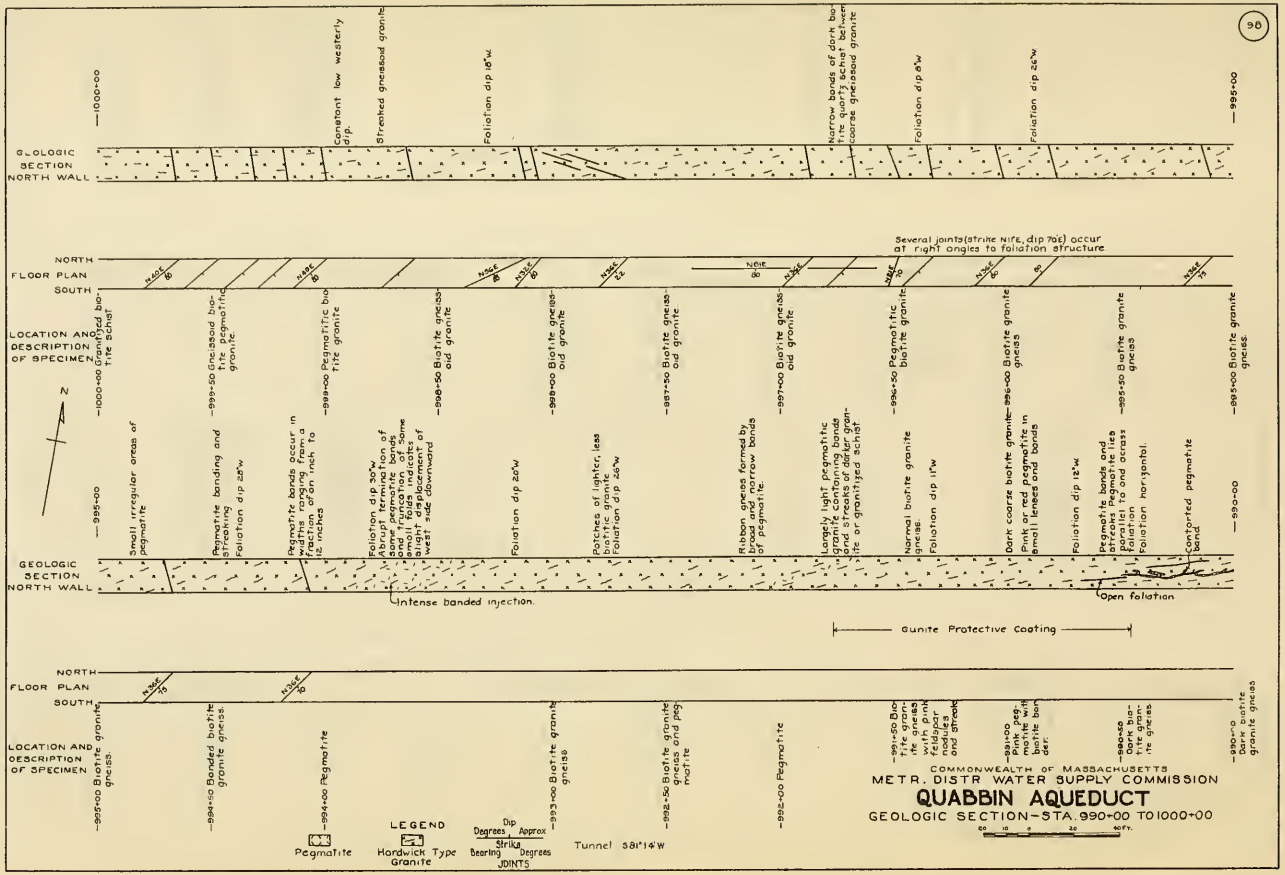

92
GEOLOGIC SECTION NORTH WALL
940+00
Foliation dip 47°W
Interbanded dark granite and porphyritic granite.
Highly porphyritic. Large feldspar crystals.
Dark Hardwick type of granite
Dark granite or highly granitized schist occurs in porphyritic granite.
Foliation dip 24°W
Coarse gneissoid granite or injection gneiss with large (1) feldspar crystals. The rock also contains some garnets.
A dark granitized schist occurs intermingled with the coarser porphyritic type.
Porphyritic garnetiferous gneiss (Coy's Hill granite type) Narrow schist bands.
Highly garnetiferous schist, which is soft and much injected
Foliation dip 25°W
Biotite injection schist
Interbedded medium hard and soft schist. Pegmatite streaks, bands and lenses
Irregular small pegmatite bodies.
Beds of soft biotite schist
935+00
PORPHYRITIC BIOTITE GRANITE
COYS HILL GRANITE.
GARNETIFEROUS BIOTITE SCHIST
BRIMFIELD - WARE SCHIST
CONTACT
Gunite protective coat on roof
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
940+00 Biotite gneiss with pegmatite
939+50 Porphyritic biotite gneiss
939+00 Biotite gneiss with pegmatite.
938+50 Porphyritic biotite gneiss.
938+00 Porphyritic biotite gneiss.
937+50 Porphyritic biotite gneiss.
937+00 Porphyritic biotite gneiss with garnet
936+50 Garnetiferous biotite injection schist Porphyritic biotite gneiss.
936+00 Garnetiferous biotite injection schist.
935+50 Garnetiferous biotite injection schist and pegmatite.
935+00 Biotite quartz schist
N
935+00
Foliation dip 25°W
Pegmatite appears to follow old joint
Black biotite schist with pegmatite streaks and lenses.
Soft biotite injection schist occurring in beds
Foliation dip 25°W
Pegmatite
Beds of harder more quartzose schist and granitized schist occur
Garnets occur throughout
Strike N11°E
Foliation dip 18°W
Soft biotite schist and pegmatite in lenses, bands, and streaks
Pegmatite
Foliation dip 21°W
930+00
Gunite protective coat on roof
935+00 Biotite quartz schist.
934+50 Banded granitized schist.
934+00 Garnetiferous biotite injection schist.
933+50 Garnetiferous biotite injection schist.
933+00 Gray foliated granite
932+00 Garnetiferous biotite schist.
931+00 Garnetiferous biotite schist.
930+00 Granitized biotite schist and pegmatite
LEGEND
Granite and Biotite gneiss
Brimfield Type Injection schist
Brimfield Type Schist
Dip Degrees Approx
Strike Bearing Degrees
JOINTS
Tunnel S81°14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION-STA. 930+00 TO 940+00
20 10 0 20 40 FT

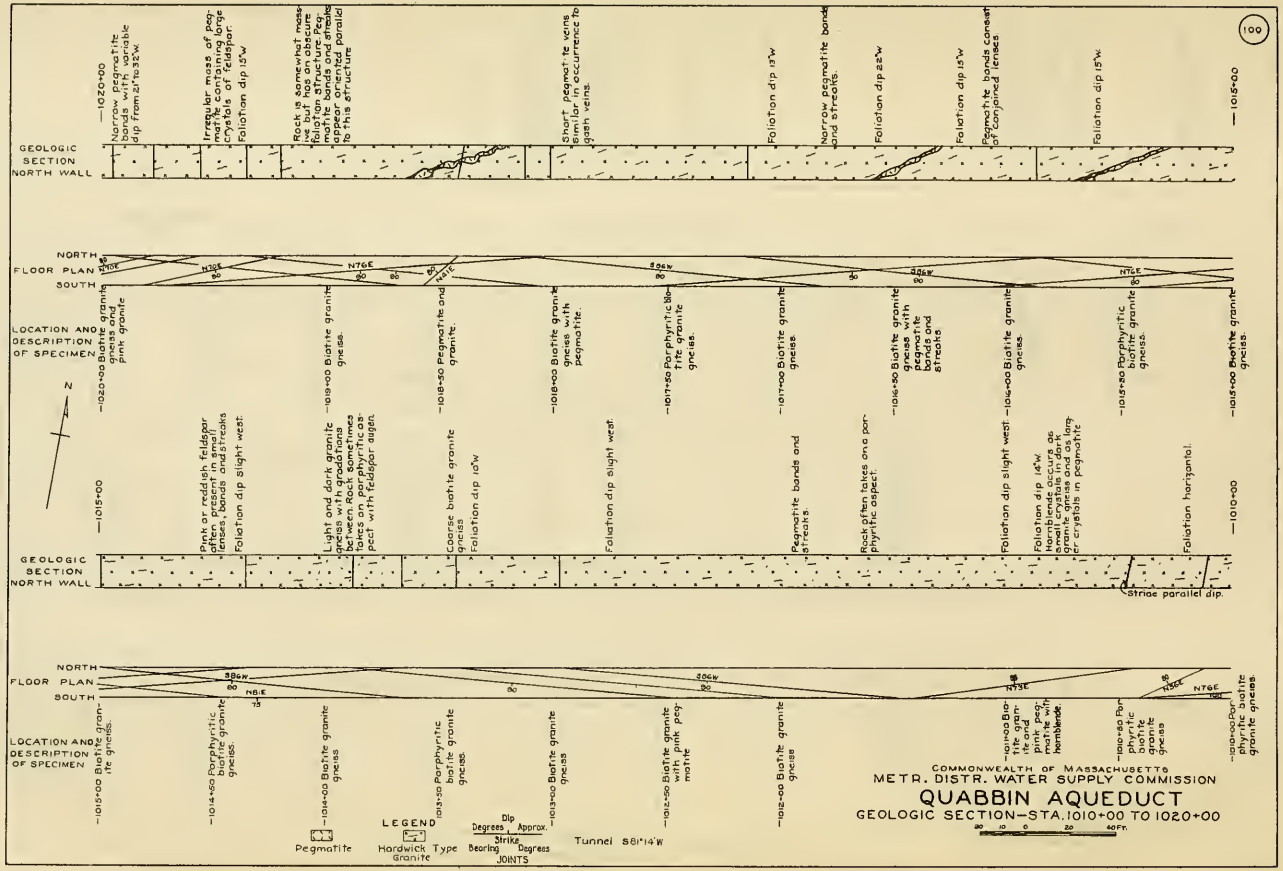
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 940+00 TO 950+00
SCALE
FEET
GEOLOGIC SECTION NORTH WALL
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
—950+00
Foliation dip 24°W
Coarse granite and pegmatite
Hard and soft rock are distributed in beds. The softer rocks appear similar and behave much like the Brimfield type of schist. These are of a fairly biotite schist, highly granitized and contain much pegmatite in streaks and bands. The harder beds are highly granitized and more quartzose.
Foliation dip 11°W
Banded injection. Light and dark gneissoid granite.
Foliation dip 24°W
Narrow bands of foliated granite
Inter-bedded hard and soft schist typical fairly biotite mica schist
Foliation dip 22°W
Bandded injection. Biotite mica schist
Foliation dip 22°W
Biotite gneiss which contains pegmatite streaks
Bands of coarse granite or pegmatite
Foliation dip 22°W
—945+00
GARNETIFEROUS BIOTITE SCHIST
DRINFIELD-WARE SCHIST
PORPHYRITIC BIOTITE GRANITE
COYS HILL GRANITE
—950+00 Granitized biotite schist and pegmatite.
Foliation dip 37°W
—949+50 Granitized biotite schist and pegmatite
Porphyritic gneiss or granite
About 60% of the rock is made up of feldspar crystals or dark granitized schist groundmass.
—949+00 Granitized schist.
A finer grained and non-porphyritic dark granite or schist occurs
—948+50 Bandded granitized schist
Foliation 14°W
Large feldspar crystals occur.
—948+00 Highly granitized schist
Black biotite gneiss containing pegmatite. A tectonic or porphyritic texture is the development of
Foliation dip 22°W
—947+50 Garnetiferous biotite schist with pegmatite
Dark granite gneiss hornwick type
—947+00 Foliated granite
Foliation dip 47°W
Irregular pegmatite veins
Hard massive gneiss.
horsewick type of gneiss
Coarse porphyritic gneiss
—946+50 Garnetiferous injection schist
Foliation dip 35°W
Mixed white pegmatite and coarse granite with
—946+00 Garnetiferous injection schist
Darker granitized schist
Bands. A light gray fine grained granite also occurs.
Porphyritic gneiss with well formed Carlsbad twins of feldspar.
Highly porphyritic
Zone of coarse granite and pegmatite which merges into porphyritic type
Foliation dip 31°W
—945+50 Gray granite
Pegmatite or coarse granite containing narrow bands and lens-like bodies
Granitized schist Merges on either side into porphyritic granite
Dark granite or highly granitized schist
—945+00
—944+50 Porphyritic biotite gneiss
Jointing is not prominent.
—944+00 Porphyritic biotite gneiss
—943+50 Porphyritic biotite gneiss.
—943+00 Porphyritic biotite gneiss.
Tunnel S 81°14'W
—942+50 Porphyritic biotite gneiss.
—942+00 Dark biotite gneiss.
Horsewick type of gneiss
Fine gneiss
—941+50 Coarse granite, dark biotite gneiss
—941+00 Porphyritic biotite gneiss
—940+50 Porphyritic biotite gneiss
—940+00 Biotite gneiss with pegmatite.
LEGEND
Granite and biotite gneiss
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees
Approx. Strike Bearing
Degrees
JOINTS

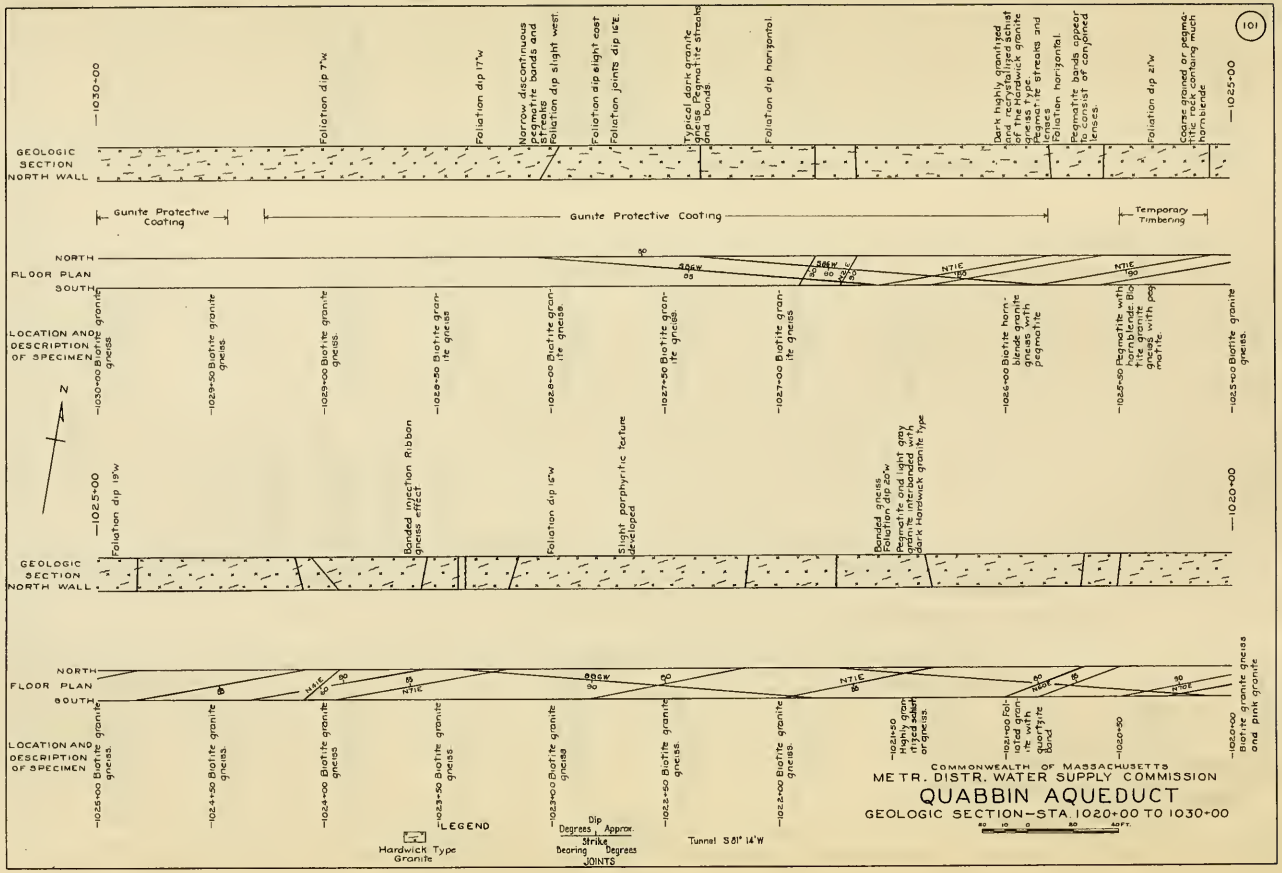

95
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 960+00 TO 970+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
970+00
965+00
960+00
Small pegmatite lenses and narrow bands.
Large pegmatite bodies have a foliation structure or orientation of mica parallel to that of surrounding gneiss.
Foliation dip 15°W.
Scattered crystals or phenocrysts of feldspar
Dark biotite granite gneiss slightly porphyritic and streaked with pegmatite
Foliation dip slight west
Foliation dip 21°W
Rock through this section is soft and flaky. Some clay gouge on foliation surfaces.
Banded biotite granite gneiss.
Foliation dip 15°W
Rock is sometimes strongly gneissoid and streaked
Banded injection.
Foliation dip 16°W.
Lenticular bands or sills of pegmatite grade into gneiss through zone of bonded injection.
Foliation dip 13°W
Permanent Timbering
Gunite Protective Coating
A feature of this section is the absence of any prominent joint system
970+00 Biotite granite gneiss
969+50 Granitized biotite schist with pegmatite streaks
969+00 Pegmatite and biotite schist
968+00 Garnetiferous muscovite schist
967+00 Granitized biotite schist.
966+50 Garnetiferous biotite schist with pegmatite streaks and bands
966+00 Pegmatite with garnet
965+50 Garnetiferous granitized biotite schist.
965+00 Biotite granitized schist Biotite schist with pegmatite bands
Foliation dip 13°W.
Small lenses aligned in bands Bands of granitized schist
Foliation dip 18°W
Banded injection Somewhat flaky biotite Type of schist.
Pegmatite streaks, bands, and lenses.
Foliation dip 13°W
The rock throughout this section resembles that occurring throughout the east and west tunnels of shaft 9 The occurrence of granite is more prominent, however, and the schist is recrystallized to a greater extent.
Narrow(?) granite bands. Wide bands of pegmatite and foliated granite Less granitized schist resembles Brimfield type
Foliation dip 21°W
Lens with granite core and pegmatitic border Bonded injection.
Foliation dip 14°W Narrow bands of granite and pegmatite occur parallel to foliation of soft biotite schist.
Strongest jointing appears to be parallel to or at acute angles to tunnel sidewalls
965+00 Biotite granitized schist Biotite schist with pegmatite band
964+50 Biotite schist with granitized bands and pegmatite streaks and lenses
964+00 Garnetiferous biotite schist with pegmatite streaks
963+50 Garnetiferous granitized biotite schist
963+00 Garnetiferous granitized biotite schist.
962+50 Granitized biotite schist
962+00 Garnetiferous granitized schist with pegmatite bands
961+50 Garnetiferous biotite schist with pegmatite
961+00 Biotite quartzose schist. Gray granite
960+50 Garnetiferous biotite injection schist
960+00 Granite with biotite schist borders
LEGEND
Pegmatite
Brimfield Type Injection Schist
Brimfield Type Schist
Dip Degrees Approx. Strike Bearing Degrees JOINTS
Tunnel S81°14'W
N

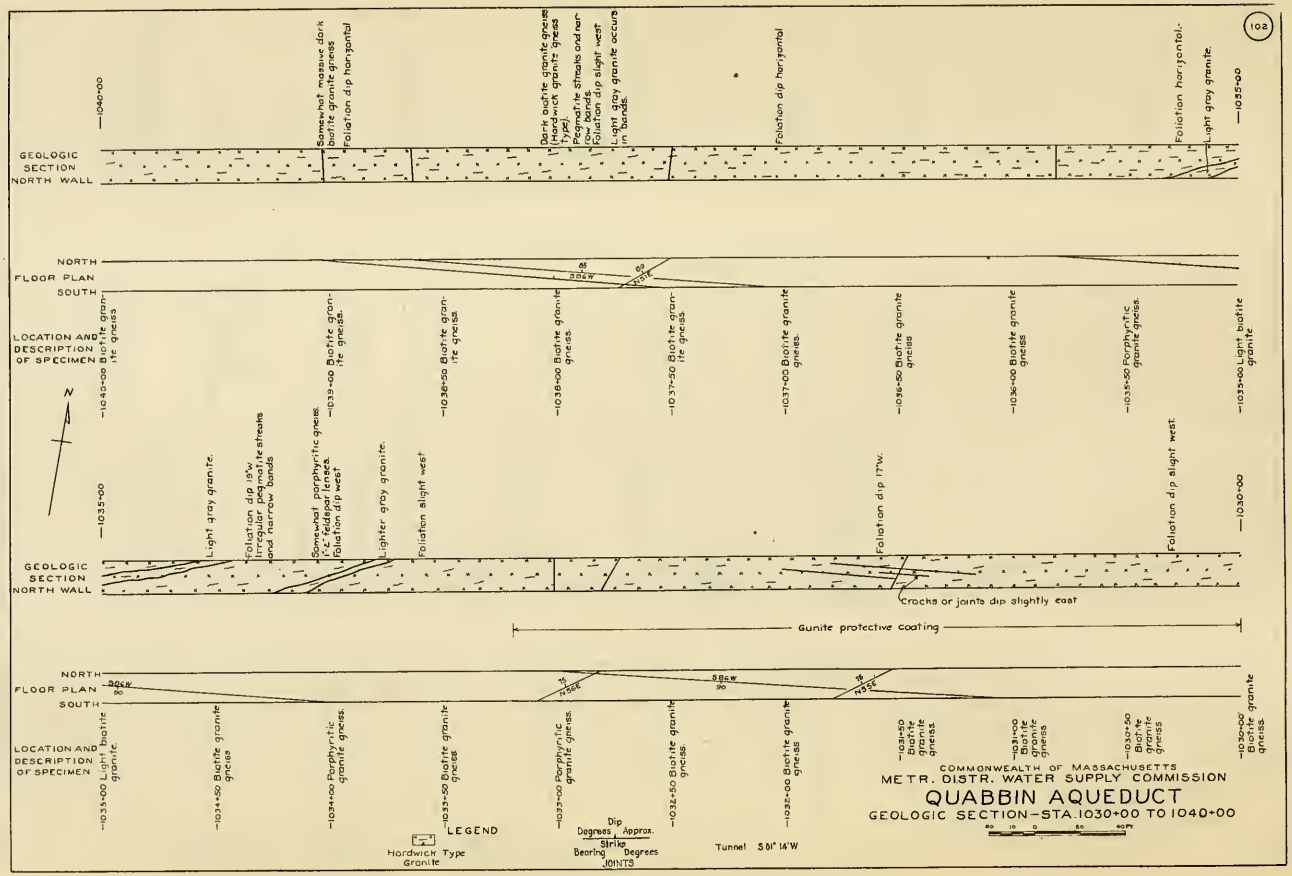

GEOLOGIC SECTION NORTH WALL
—980+00
Much lighter gray granite occurs in wide bands which grades into the darker granite gneiss.
Narrow (±) pegmatite bands. Foliation dip 26°W Joints dip parallel to foliation.
Foliation dip 32°W Dark biotite schistose rock. Pegmatite streaks, bands and lenses of crystals of feldspar. Foliation dip 45°W
Steep foliation indicated by the tendency of pegmatite bands.
Pegmatite streaks and bands. Foliation dip 36°W
Biotite granite gneiss
Foliation dip 15°W
Pegmatite band made up of conjoined lenses.
Foliation slight west dip
Irregular areas and blotches of pegmatite
Pegmatite here is of the pink feldspar variety
Zones of coarse pegmatite granite in fine grained biotite granite gneiss
Foliation slight west dip
—975+00
Joints dip at right angles to foliation. Strike N0°E
NORTH
FLOOR PLAN
SOUTH
N60E 45
N60E 60
70 N80E
LOCATION AND DESCRIPTION OF SPECIMEN
N
—975+00
Lenticular pegmatite mass.
Foliation dip 38°W Pegmatite band
Lens-like body of pegmatite with granite core
Pink pegmatite occurs in streaks and lenses and pegmatite composed chiefly of pink or reddish feldspar as compared to former more frequent occurrence of white feldspar.
Foliation dip 24°W
Granitized schist is banded and streaked and also porphyritic. Rock is slightly garnetiferous
Foliation dip 32°W
Narrow pegmatite bands
Foliation dip 22°W
Rock is slightly biotitic with ½ feldspar crystals
Much pegmatite banding
Foliation dip 20°W
—970+00
—980+00 Gray granite
—979+50 Biotite granite gneiss
—979+00 Biotite schist with pegmatite lenses and streaks
—978+50 Biotite schist with feldspar crystals
—978+00 Biotite granite gneiss.
—977+50 Gray biotite granite with pegmatite
—977+00 Biotite granite gneiss
—976+50 Biotite granite gneiss
—976+00 Pink pegmatite.
—975+50 Biotite granite gneiss with pink pegmatite
—975+00 Biotite granite gneiss
GEOLOGIC SECTION NORTH WALL
Numerous small joints or fractures at right angles to foliation Strike N0°E
Fractures at right angles to foliation.
Note; At about station 973+00 there appears to be a change in rock character. East of here the rock is decidedly more schistose, of the flaky brown biotite variety or of the Brimfield schist type. West of here the rock is a hard thoroughly crystalline black biotite granite or gneiss, the Hardwick granite type
A dominant direction of jointing is lacking but the rock is somewhat blocky.
NORTH
FLOOR PLAN
SOUTH
N60E 45
N70E 85
N60E 45
N70E 60
N70E 90
N70E 80
N24W 80
LOCATION AND DESCRIPTION OF SPECIMEN
—973+50 Biotite granite gneiss
—974+50 Biotite granite gneiss
—974+00 Gray biotite granite with pegmatite
—973+50 Biotite granite with pink pegmatite
—973+00 Biotite granite and pink pegmatite
—972+50 Biotite granite
—972+00 Biotite schist with pegmatite streaks and garnet
—971+00 Gray biotite granite
—970+50 Gray biotite granite
—970+00 Biotite granite gneiss
LEGEND
Pegmatite
Brimfield Type Injection Schist
Hardwick Type Granite
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel 38°14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 970+00 TO 980+00
80 40 0 80 160 FT.

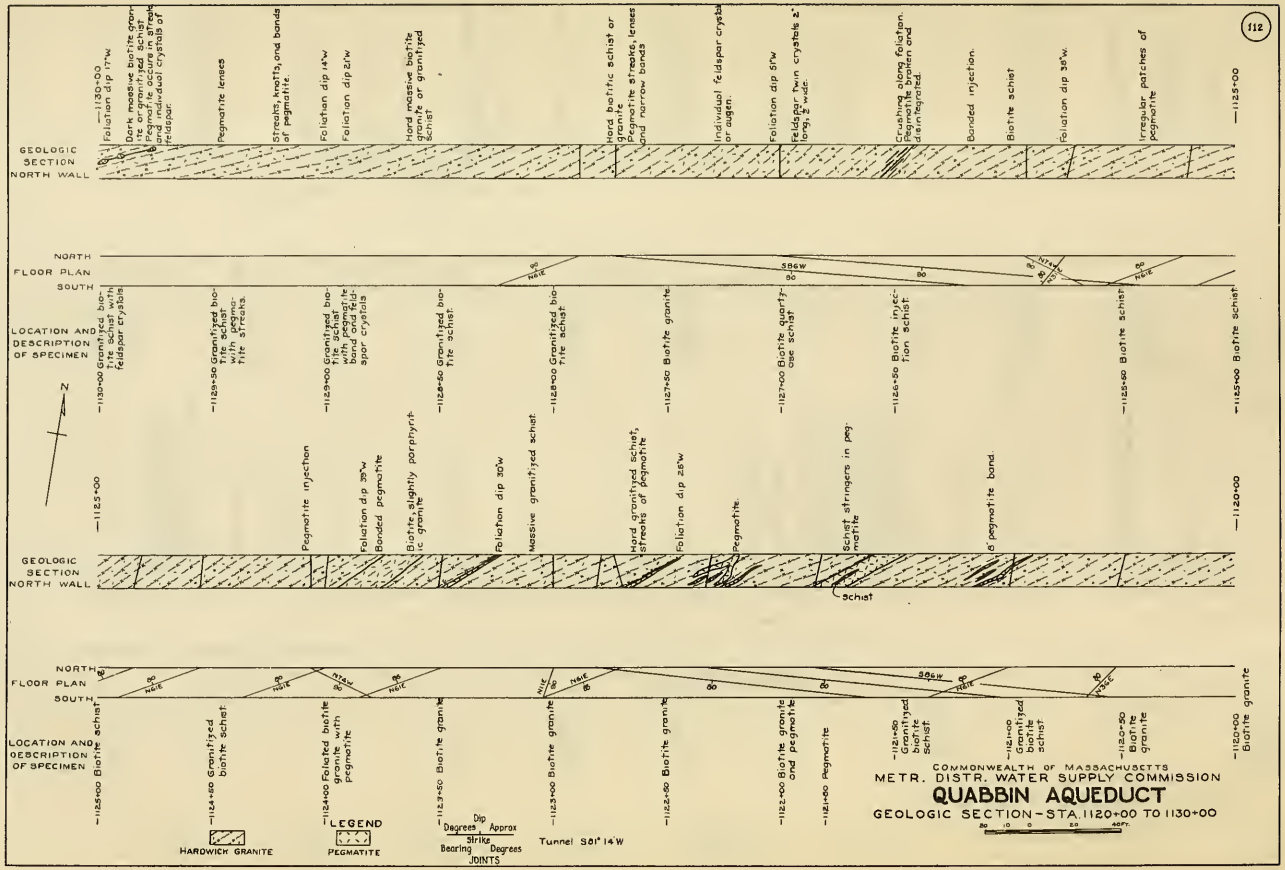

GEOLOGIC SECTION NORTH WALL
—990+00
Narrow pegmatite bands
Foliation dip 12°W
2' pegmatite band
— SHAFT 10
Foliation slight west dip
Gneiss Contains Pink 5" Gneiss & feldspar crystal lenses.
Small (1"-2") pegmatite lenses occur in groups. Also in bands. Strike N0°E Foliation Dip 8°W
Hard black biotite gneiss. Near top part of rock composed of black biotite and possibly other minerals. Lower part with quartz and larger crystals of feldspar. Hand specimen shows lots of feldspar crystals occur as well.
Structure through here is somewhat massive
Foliation dip slightly west
Pegmatite streaks and bands
Section through here largely made up of porphyritic dark granite gneiss.
Pegmatite in small folds
Foliation dip 7°W
Dark biotite granite gneiss
About 5% pegmatite in lenses, streaks and bands
Foliation dip 4°W
—985+00
Gunite Protective Coating
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—990+00 Dark biotite granite gneiss
—989+50 Dark biotite granite gneiss
—989+00 Dark biotite granite gneiss
—988+50 Dark biotite granite gneiss
—988+00 Dark biotite granite gneiss
—987+50 Dark biotite granite gneiss
—987+00 Dark biotite granite gneiss
—986+50 Foliated biotite granite
—986+00 Biotite granite with pegmatite lenses
—985+50 Biotite granite gneiss
—985+00 Porphyritic biotite granite
N
—985+00
Pink pegmatite bands
Foliation 10°W
Several foliation joints of five-foot intervals.
Foliation dip 42°W
Foliation dip 8°W
Massive biotite granite gneiss
Bands of much lighter granite.
Foliation dip 22°W
Gneissoid granite. Pegmatite in form of streaks, bands occurs as large part of rock.
Foliation slight west dip
—980+00
GEOLOGIC SECTION NORTH WALL
Cracks which parallel foliation structure are essentially joints.
Minor fractures at right angles to foliation strike N0°E
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—985+50 Porphyritic biotite granite
—985+50 Porphyritic biotite granite pegmatite
—984+50 Biotite schist
—983+50 Biotite granite gneiss
—983+00 Porphyritic biotite granite
—982+50 Foliated biotite granite with pegmatite streaks
—982+00 Biotite granite gneiss
—981+50 Gray granite
—980+50 Biotite granite with pegmatite
—980+00 Biotite granite gneiss
—980+00 Gray granite
Pegmatite
LEGEND
Hardwick Type Granite
Dip Degrees, Approx. Strike Bearing Degrees
JOINTS
Tunnel S81°14W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 980+00 TO 990+00
40 10 0 20 40 FT.

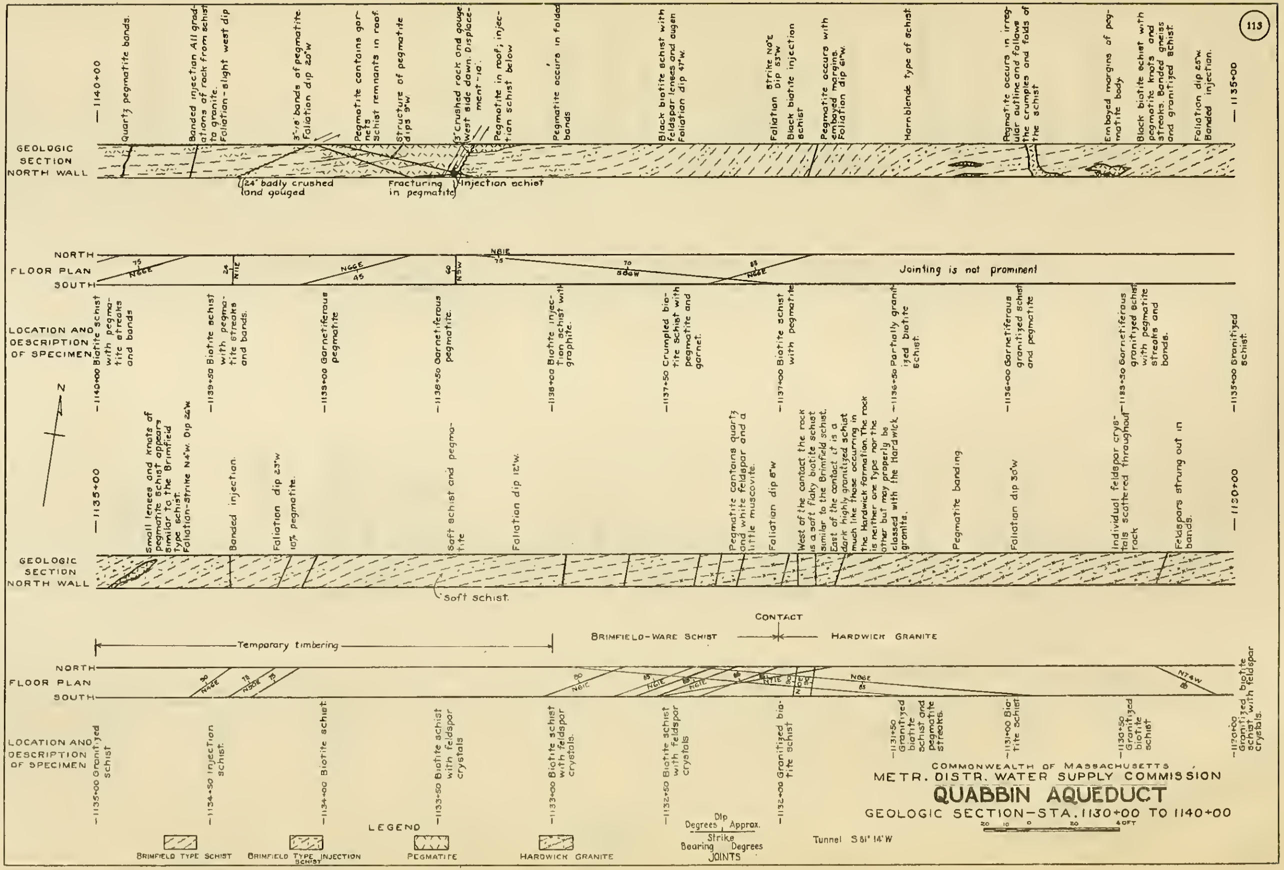

98
GEOLOGIC SECTION NORTH WALL
1000+00
Constant low westerly dip.
Streaked gneissoid granite
Foliation dip 18°W.
Narrow bands of dark biotite quartz schist between coarse gneissoid granite
Foliation dip 8°W
Foliation dip 26°W
995+00
NORTH
FLOOR PLAN
SOUTH
Several joints (strike N16E, dip 70°E) occur at right angles to foliation structure.
LOCATION AND DESCRIPTION OF SPECIMEN
1000+00 Granitized biotite schist
999+50 Gneissoid biotite pegmatitic granite.
999+00 Pegmatitic biotite granite
998+50 Biotite gneissoid granite
998+00 Biotite gneissoid granite
997+50 Biotite gneissoid granite
997+00 Biotite gneissoid granite
996+50 Pegmatitic biotite granite
996+00 Biotite granite gneiss
995+50 Biotite granite gneiss
995+00 Biotite granite gneiss.
N
995+00
Small irregular areas of pegmatite
Pegmatite banding and streaking
Foliation dip 28°W
Pegmatite bands occur in widths ranging from a fraction of an inch to 12 inches
Foliation dip 30°W
Abrupt termination of some pegmatite bands and formation of some small folds indicates slight displacement of west side downward
Foliation dip 26°W
Patches of lighter, less biotitic granite
Foliation dip 26°W
Ribbon gneiss formed by broad and narrow bands of pegmatite.
Largely light pegmatitic granite containing bands and streaks of darker granite or granitized schist
Normal biotite granite gneiss.
Foliation dip 11°W
Dark coarse biotite granite
Pink or red pegmatite in small lenses and bands
Foliation dip 12°W
Pegmatite bands and streaks Pegmatite lies parallel to and across foliation
Foliation horizontal.
Contorted pegmatite band
990+00
GEOLOGIC SECTION NORTH WALL
Intense banded injection.
Open foliation
Gunite Protective Coating
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
995+00 Biotite granite gneiss.
994+50 Banded biotite granite gneiss.
994+00 Pegmatite
993+00 Biotite granite gneiss
992+50 Biotite granite gneiss and pegmatite
992+00 Pegmatite
991+50 Biotite granite gneiss with pink feldspar nodules and streak
991+00 Pink pegmatite with biotite border.
990+50 Dark biotite granite gneiss
990+00 Dark biotite granite gneiss
LEGEND
Pegmatite
Hardwick Type Granite
Dip Degrees Approx
Strike Bearing Degrees
JOINTS
Tunnel S81°14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 990+00 TO 1000+00
50 10 0 20 40 FT.

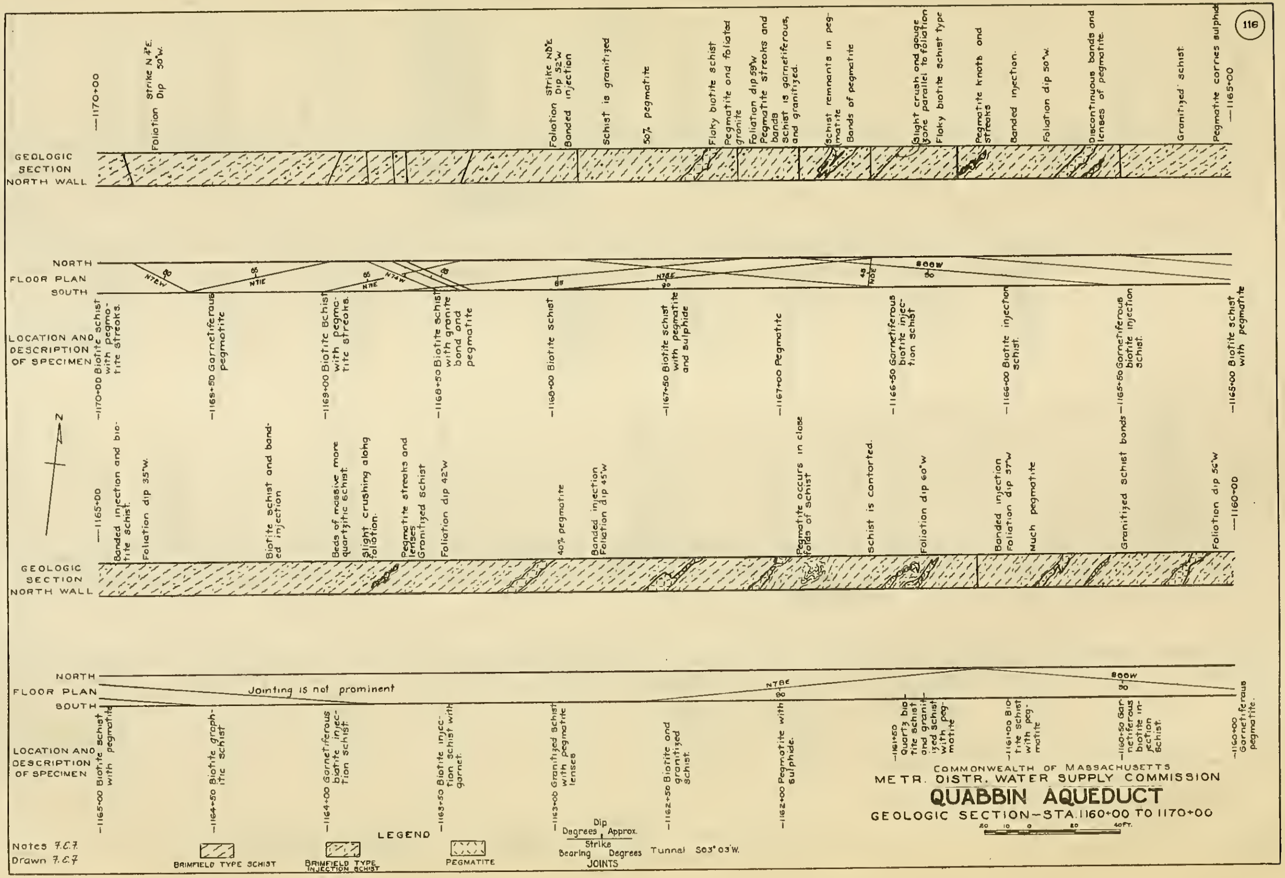

100
GEOLOGIC SECTION NORTH WALL
1020+00
Narrow pegmatite bands with variable dip from 21° to 32° W.
Irregular mass of pegmatite containing large crystals of feldspar.
Foliation dip 15° W
Rock is somewhat massive but has an obscure foliation structure. Pegmatite bands and streaks appear oriented parallel to this structure
Short pegmatite veins similar in occurrence to gash veins.
Foliation dip 13° W
Narrow pegmatite bands and streaks.
Foliation dip 22° W
Foliation dip 15° W
Pegmatite bands consist of conjoined lenses
Foliation dip 15° W.
1015+00
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
1020+00 Biotite granite gneiss and pink granite
1019+00 Biotite granite gneiss.
1018+50 Pegmatite and granite.
1018+00 Biotite granite gneiss with pegmatite.
1017+50 Porphyritic biotite granite gneiss.
1017+00 Biotite granite gneiss.
1016+50 Biotite granite gneiss with pegmatite bands and streaks.
1016+00 Biotite granite gneiss.
1015+50 Porphyritic biotite granite gneiss.
1015+00 Biotite granite gneiss.
1015+00
Pink or reddish feldspar often present in small lenses, bands and streaks
Foliation dip slight west.
Light and dark granite gneiss with gradations between. Rock sometimes takes on porphyritic aspect with feldspar augen.
Coarse biotite granite gneiss
Foliation dip 10° W
Foliation dip slight west.
Pegmatite bands and streaks.
Rock often takes on a porphyritic aspect.
Foliation dip slight west.
Foliation dip 14° W. Hornblende occurs as small crystals in dark granite gneiss and as larger crystals in pegmatite
Foliation horizontal.
1010+00
Striae parallel dip.
1015+00 Biotite granite gneiss.
1014+50 Porphyritic biotite granite gneiss.
1014+00 Biotite granite gneiss
1013+50 Porphyritic biotite granite gneiss.
1013+00 Biotite granite gneiss
1012+50 Biotite granite with pink pegmatite
1012+00 Biotite granite gneiss
1011+00 Biotite granite and pink pegmatite with hornblende.
1010+50 Porphyritic biotite granite gneiss
1010+00 Porphyritic biotite granite gneiss.
LEGEND
Pegmatite
Hardwick Type Granite
Dip
Degrees
Approx.
Strike
Bearing
Degrees
JOINTS
Tunnel S81°14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1010+00 TO 1020+00
20 10 0 20 40 FT.

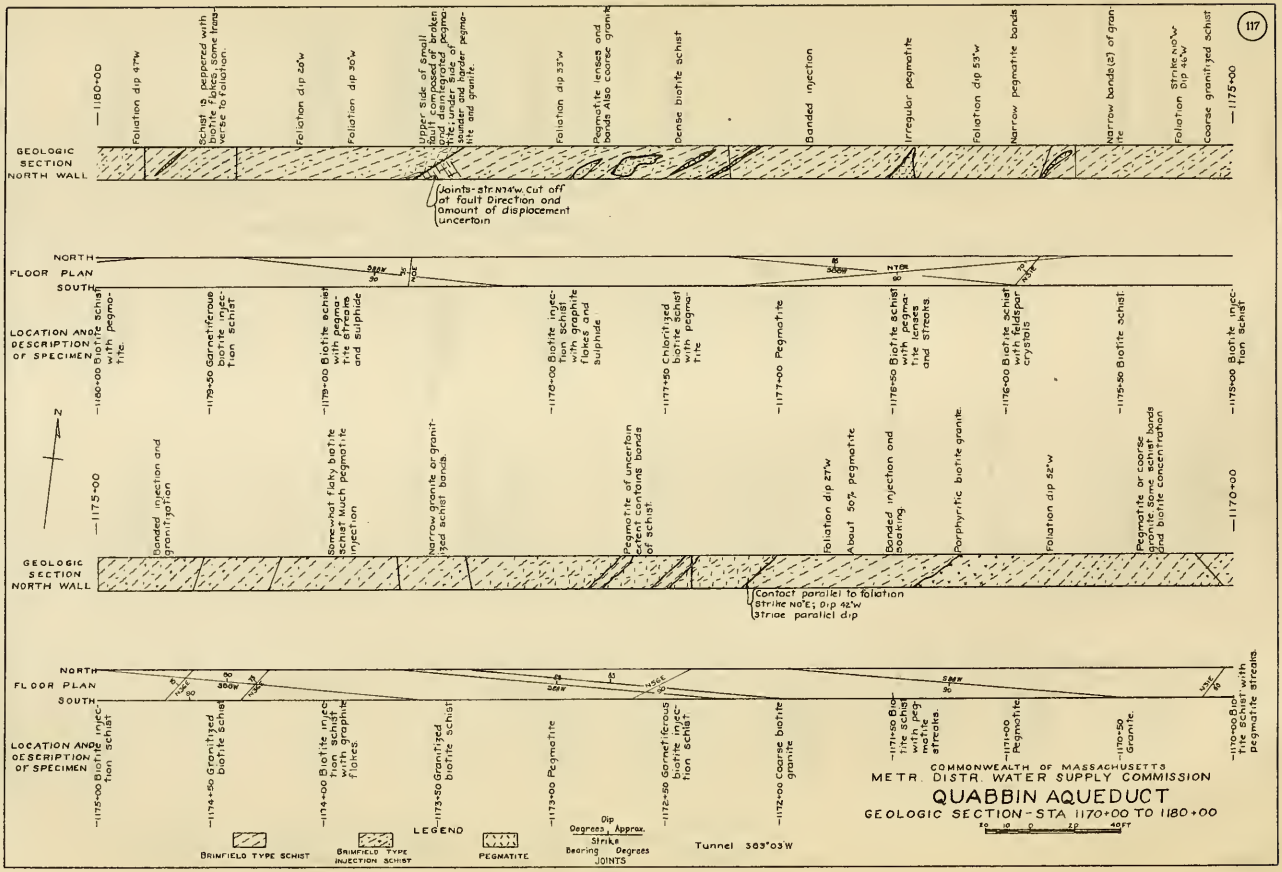

GEOLOGIC SECTION NORTH WALL
—1030+00
Foliation dip 7°W
Foliation dip 17°W
Narrow discontinuous pegmatite bands and veinlets
Foliation dip slight west.
Foliation dip slight east
Foliation joints dip 16°E.
Typical dark granite gneiss. Pegmatite streaks and bands
Foliation dip horizontal.
Dark highly granitized and recrystallized schist and Hardwick granite gneiss type
Pegmatite streams and veinlets
Foliation horizontal.
Pegmatite bands appear to consist of conjoined lenses.
Foliation dip 21°W
Coarse grained or pegmatitic rock containing much hornblende
—1025+00
Gunite Protective Coating
Gunite Protective Coating
Temporary Timbering
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—1030+00 Biotite granite gneiss.
—1029+50 Biotite granite gneiss.
—1029+00 Biotite granite gneiss.
—1028+50 Biotite granite gneiss
—1028+00 Biotite granite gneiss.
—1027+50 Biotite granite gneiss.
—1027+00 Biotite granite gneiss
—1026+00 Biotite hornblende granite gneiss with pegmatite
—1025+50 Pegmatite with hornblende Biotite granite gneiss with peg matite.
—1025+00 Biotite granite gneiss.
N
GEOLOGIC SECTION NORTH WALL
—1025+00
Foliation dip 19°W
Banded injection Ribbon gneiss effect
Foliation dip 16°W
Slight porphyritic texture developed
Banded gneiss. Foliation dip 20°W
Pegmatite and light gray granite interbanded with dark Hardwick granite type
—1020+00
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—1025+00 Biotite granite gneiss.
—1024+50 Biotite granite gneiss.
—1024+00 Biotite granite gneiss
—1023+50 Biotite granite gneiss.
—1023+00 Biotite granite gneiss
—1022+50 Biotite granite gneiss.
—1022+00 Biotite granite gneiss.
—1021+50 Highly granitized schist or gneiss.
—1021+00 Foliated coarse granite with quartzite band
—1020+50
—1020+00 Biotite granite gneiss and pink granite
LEGEND
Hardwick Type Granite
Dip Degrees, Approx. Strike Bearing Degrees
JOINTS
Tunnel S 81° 14' W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1020+00 TO 1030+00
40 10 0 80 40 FT.

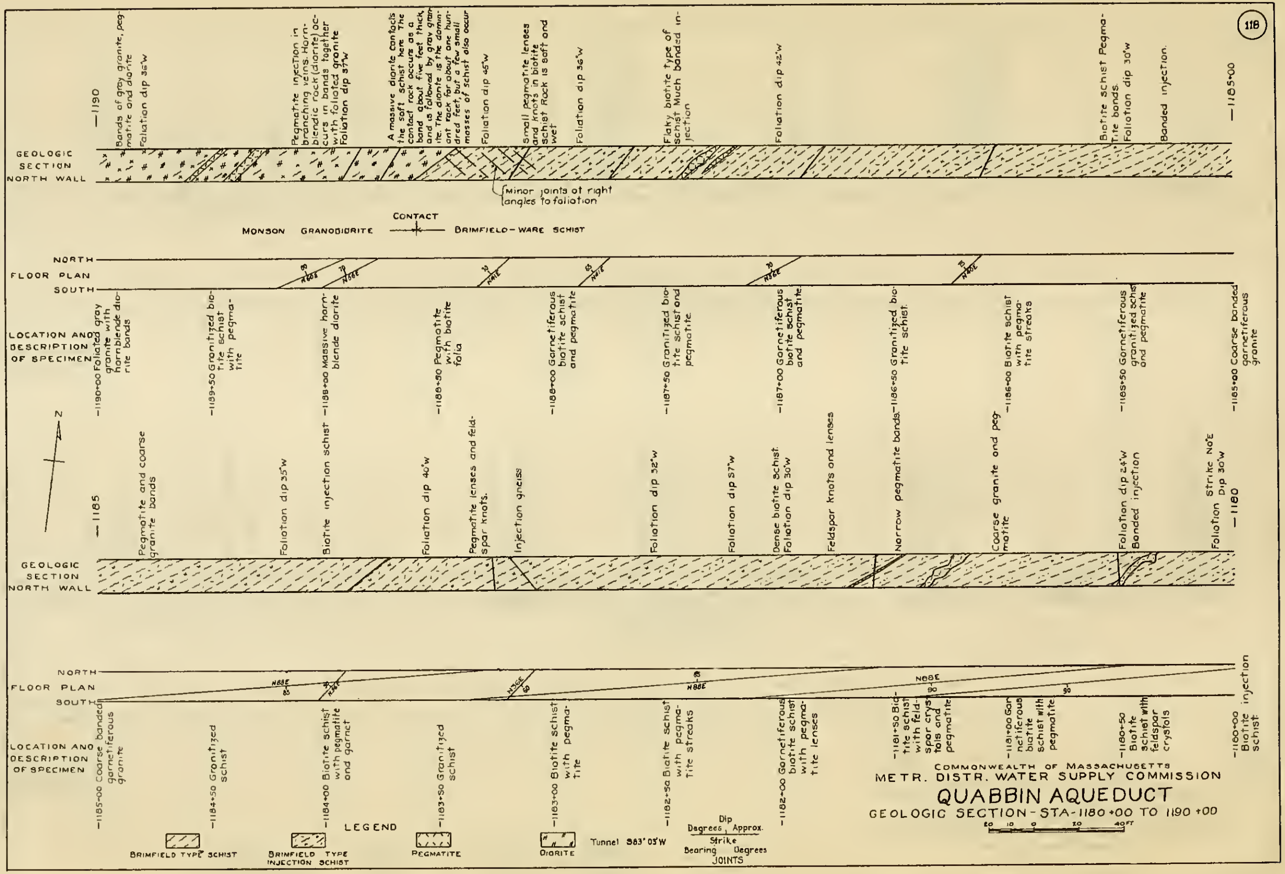

GEOLOGIC SECTION NORTH WALL
—1040+00
Somewhat massive dark biotite granite gneiss
Foliation dip horizontal
Dark biotite granite gneiss (Hardwick granite gneiss type). Pegmatite streaks and narrow bands
Foliation dip slight west
Light gray granite occurs in bands.
Foliation dip horizontal
Foliation horizontal
Light gray granite
—1035+00
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—1040+00 Biotite granite gneiss
—1039+00 Biotite granite gneiss.
—1038+50 Biotite granite gneiss.
—1038+00 Biotite granite gneiss.
—1037+50 Biotite granite gneiss.
—1037+00 Biotite granite gneiss.
—1036+50 Biotite granite gneiss
—1036+00 Biotite granite gneiss
—1035+50 Porphyritic granite gneiss.
—1035+00 Light biotite granite
N
GEOLOGIC SECTION NORTH WALL
—1035+00
Light gray granite.
Foliation dip 18°W. Irregular pegmatite streaks and narrow bands
Somewhat porphyritic gneiss. F.C. feldspar lenses. Foliation dip west
Lighter gray granite.
Foliation slight west
Foliation dip 17°W.
Foliation dip slight west
—1030+00
Cracks or joints dip slightly east
Gunite protective coating
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—1035+00 Light biotite granite.
—1034+50 Biotite granite gneiss
—1034+00 Porphyritic granite gneiss.
—1033+50 Biotite granite gneiss
—1033+00 Porphyritic granite gneiss.
—1032+50 Biotite granite gneiss
—1032+00 Biotite granite gneiss
—1031+50 Biotite granite gneiss.
—1031+00 Biotite granite gneiss
—1030+50 Biotite granite gneiss
—1030+00 Biotite granite gneiss.
LEGEND
Hardwick Type Granite
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
Tunnel S 81° 14' W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1030+00 TO 1040+00

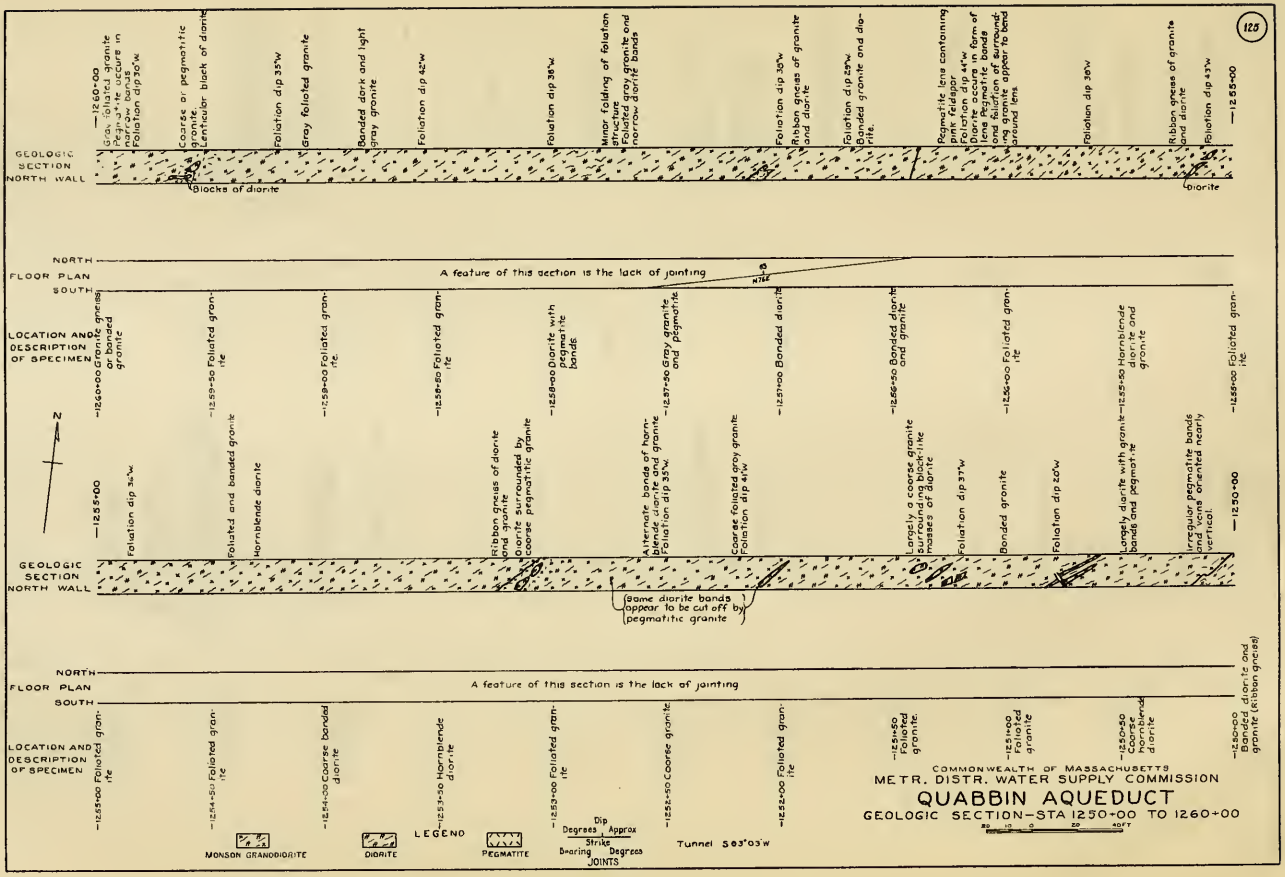

GEOLOGIC SECTION NORTH WALL
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
N
1130+00 Foliation dip 17°W
Dark massive biotite granite or granitized schist
Pegmatite occurs in streaks and individual crystals of feldspar
Pegmatite lenses
Streaks, knotts, and bands of pegmatite.
Foliation dip 14°W
Foliation dip 21°W
Hard massive biotite granite or granitized schist
Hard biotitic schist or granite
Pegmatite streaks, lenses and narrow bands
Individual feldspar crystals or augen.
Foliation dip 5°W
Feldspar twin crystals 2" long, ½" wide.
Crushing along foliation. Pegmatite broken and disintegrated.
Banded injection.
Biotite schist
Foliation dip 36°W.
Irregular patches of pegmatite
1125+00
1130+00 Granitized biotite schist with feldspar crystals
1129+50 Granitized biotite schist with pegmatite streaks.
1129+00 Granitized biotite schist with pegmatite band and feldspar crystals
1128+50 Granitized biotite schist.
1128+00 Granitized biotite schist
1127+50 Biotite granite
1127+00 Biotite quartzose schist
1126+50 Biotite injection schist.
1125+50 Biotite schist
1125+00 Biotite schist
1125+00
Pegmatite injection
Foliation dip 39°W
Banded pegmatite
Biotite, slightly porphyritic granite
Foliation dip 30°W
Massive granitized schist.
Hard granitized schist, streaks of pegmatite
Foliation dip 26°W
Pegmatite.
Schist stringers in pegmatite
8" pegmatite band.
schist
1120+00
1125+00 Biotite schist
1124+50 Granitized biotite schist.
1124+00 Foliated biotite granite with pegmatite
1123+50 Biotite granite
1123+00 Biotite granite
1122+50 Biotite granite
1122+00 Biotite granite and pegmatite
1121+50 Pegmatite
1121+50 Granitized biotite schist.
1121+00 Granitized biotite schist
1120+50 Biotite granite
1120+00 Biotite granite
LEGEND
HARDWICK GRANITE
PEGMATITE
Dip Degrees Approx
Strike Bearing Degrees
JOINTS
Tunnel S81° 14'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA. 1120+00 TO 1130+00
20 10 0 20 40 FT.

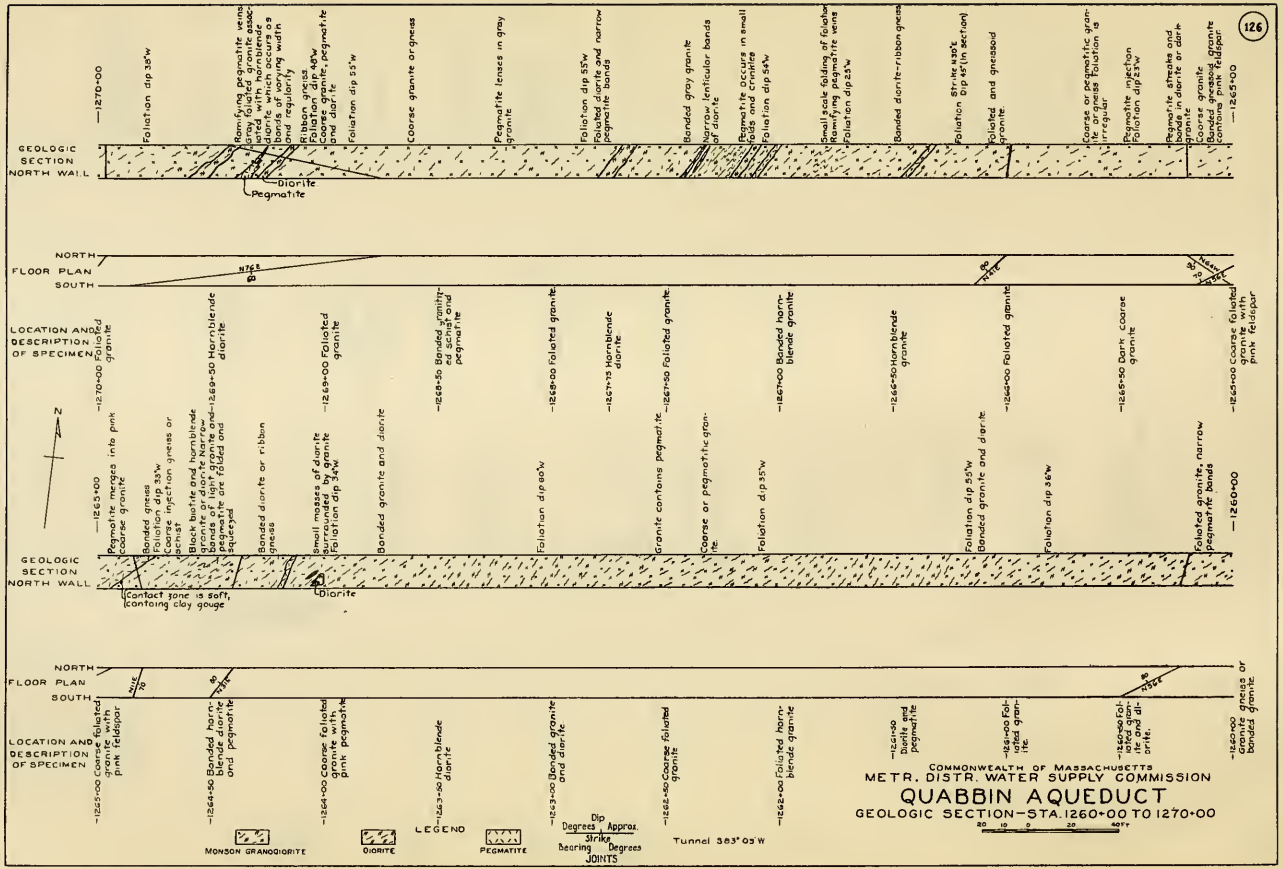

113
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1130+00 TO 1140+00
Tunnel S 61° 14' W
LEGEND
BRIMFIELD TYPE SCHIST
BRIMFIELD TYPE INJECTION SCHIST
PEGMATITE
HARDWICK GRANITE
Dip Degrees Approx.
Strike Bearing Degrees
JOINTS
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
1140+00
Quartz pegmatite bands.
Banded injection All gradations of rock from schist to granite. Foliation-slight west dip
3"-18" bands of pegmatite. Foliation dip 20°W
Pegmatite contains garnets. Schist remnants in roof.
Structure of pegmatite dips 9°W
3' Crushed rock and gouge. West side down. Displacement-10'.
Pegmatite in roof; injection schist below
Pegmatite occurs in folded bands
Black biotite schist with feldspar lenses and augen. Foliation dip 47°W.
Foliation Strike N0°E Dip 53°W
Black biotite injection schist
Pegmatite occurs with embayed margins. Foliation dip 61°W.
Hornblende type of schist
Pegmatite occurs in irregular outline and follows the crumples and folds of the schist
Embayed margins of pegmatite body.
Black biotite schist with pegmatite knots and streaks. Banded gneiss and granitized schist.
Foliation dip 65°W. Banded injection.
1135+00
24" badly crushed and gouged
Fracturing in pegmatite
Injection schist
Jointing is not prominent
1140+00 Biotite schist with pegmatite streaks and bands
1139+50 Biotite schist with pegmatite streaks and bands.
1139+00 Garnetiferous pegmatite
1138+50 Garnetiferous pegmatite.
1138+00 Biotite injection schist with graphite.
1137+50 Crumpled biotite schist with pegmatite and garnet.
1137+00 Biotite schist with pegmatite
1136+50 Partially granitized biotite schist.
1136+00 Garnetiferous granitized schist and pegmatite
1135+50 Garnetiferous granitized schist with pegmatite streaks and bands.
1135+00 Granitized schist.
1135+00
Small lenses and knots of pegmatite schist appears similar to the Brimfield type schist. Foliation-Strike N4°W. Dip 26°W
Banded injection.
Foliation dip 23°W
10% pegmatite.
Soft schist and pegmatite
Soft schist.
Foliation dip 12°W.
Pegmatite contains quartz and white feldspar and a little muscovite.
Foliation dip 8°W
West of the contact the rock is a soft flaky biotite schist similar to the Brimfield schist. East of the contact it is a dark highly granitized schist much like those occurring in the Hardwick formation. The rock is neither one type nor the other but may properly be classed with the Hardwick granite.
Pegmatite banding
Foliation dip 30°W
Individual feldspar crystals scattered throughout rock
Feldspars strung out in bands.
1130+00
Temporary timbering
BRIMFIELD-WARE SCHIST
CONTACT
HARDWICK GRANITE
1135+00 Granitized schist
1134+50 Injection schist.
1134+00 Biotite schist.
1133+50 Biotite schist with feldspar crystals
1133+00 Biotite schist with feldspar crystals.
1132+50 Biotite schist with feldspar crystals
1132+00 Granitized biotite schist
1131+50 Granitized biotite schist and pegmatite streaks.
1131+00 Biotite schist
1130+50 Granitized biotite schist
1130+00 Granitized biotite schist with feldspar crystals.

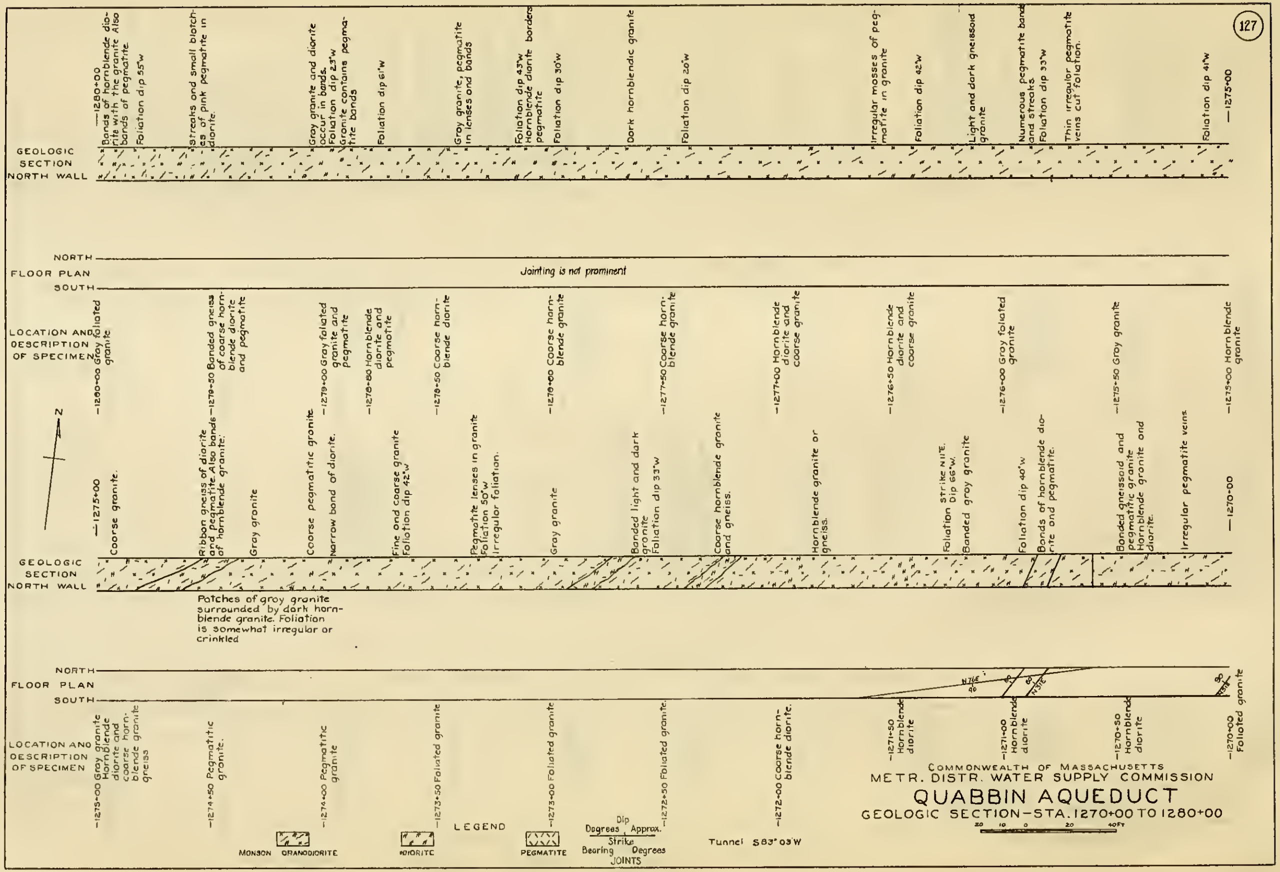

116
GEOLOGIC SECTION NORTH WALL
1170+00
Foliation strike N 4°E. Dip 50°W.
Foliation strike N 8°E Dip 52°W Banded injection
Schist is granitized
50% pegmatite
Floky biotite schist
Pegmatite and foliated granite
Foliation dip 59°W Pegmatite streaks and bands
Schist is garnetiferous, and granitized.
Schist remnants in pegmatite
Bands of pegmatite
Slight crush and gouge zone parallel to foliation
Floky biotite schist type
Pegmatite knots and streaks
Banded injection.
Foliation dip 50°W.
Discontinuous bands and lenses of pegmatite.
Granitized schist
Pegmatite carries sulphide
1165+00
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
1170+00 Biotite schist with pegmatite streaks.
1169+50 Garnetiferous pegmatite
1169+00 Biotite schist with pegmatite streaks.
1168+50 Biotite schist with granite band and pegmatite
1168+00 Biotite schist
1167+50 Biotite schist with pegmatite and sulphide
1167+00 Pegmatite
1166+50 Garnetiferous biotite injection schist
1166+00 Biotite injection schist.
1165+50 Garnetiferous biotite injection schist.
1165+00 Biotite schist with pegmatite
1165+00
Banded injection and biotite schist.
Foliation dip 35°W.
Biotite schist and banded injection
Beds of massive more quartzitic schist.
Slight crushing along foliation.
Pegmatite streaks and lenses
Granitized schist
Foliation dip 42°W
40% pegmatite
Banded injection Foliation dip 45°W
Pegmatite occurs in close folds of schist
Schist is contorted.
Foliation dip 60°W
Banded injection Foliation dip 37°W
Much pegmatite
Granitized schist bands
Foliation dip 56°W
1160+00
Jointing is not prominent
1165+00 Biotite schist with pegmatite
1164+50 Biotite graphitic schist
1164+00 Garnetiferous biotite injection schist
1163+50 Biotite injection schist with garnet.
1163+00 Granitized schist with pegmatite lenses
1162+50 Biotite and granitized schist.
1162+00 Pegmatite with sulphide.
1161+50 Quartz biotite schist and granitized schist with pegmatite
1161+00 Biotite schist with pegmatite
1160+50 Garnetiferous biotite injection schist.
1160+00 Garnetiferous pegmatite.
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1160+00 TO 1170+00
LEGEND
BRIMFIELD TYPE SCHIST
BRIMFIELD TYPE INJECTION SCHIST
PEGMATITE
Dip Degrees Approx.
Strike
Bearing Degrees
JOINTS
Tunnel S63° 03'W.
Notes F.C.F.
Drawn F.C.F.


GEOLOGIC SECTION NORTH WALL
—1180+00
Foliation dip 47°W
Schist is peppered with biotite flakes; some transverse to foliation.
Foliation dip 28°W
Foliation dip 30°W
Upper side of small fault composed of broken pegmatite, underlying pegmatite, under side of saunder and harder pegmatite and granite.
Foliation dip 53°W
Pegmatite lenses and bands Also coarse granite
Dense biotite schist
Banded injection
Irregular pegmatite
Foliation dip 53°W
Narrow pegmatite bands
Narrow bands(2) of granite
Foliation Strike N10°W Dip 46°W
Coarse granitized schist
—1175+00
Joints-str. N14°W. Cut off at fault Direction and amount of displacement uncertain
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—1180+00 Biotite schist with pegmatite.
—1179+50 Garnetiferous biotite injection schist
—1179+00 Biotite schist with pegmatite streaks and sulphide
—1178+00 Biotite injection schist with graphite flakes and sulphide
—1177+50 Chloritized biotite schist with pegmatite
—1177+00 Pegmatite
—1176+50 Biotite schist with pegmatite lenses and streaks
—1176+00 Biotite schist with feldspar crystals
—1175+50 Biotite schist
—1175+00 Biotite injection schist
N
GEOLOGIC SECTION NORTH WALL
—1175+00
Banded injection and granitization
Somewhat flaky biotite schist with pegmatite injection
Narrow granite or granitized schist bands.
Pegmatite of uncertain extent contains bands of schist.
Foliation dip 27°W
About 30% pegmatite
Banded injection and coating
Porphyritic biotite granite.
Foliation dip 52°W
Pegmatite or coarse granite some schist bands and biotite concentration
—1170+00
Contact parallel to foliation Strike N0°E; Dip 42°W Strike parallel dip
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
—1175+00 Biotite injection schist
—1174+50 Granitized biotite schist
—1174+00 Biotite injection schist with graphite flakes
—1173+50 Granitized biotite schist
—1173+00 Pegmatite
—1172+50 Garnetiferous biotite injection schist
—1172+00 Coarse biotite granite
—1171+50 Biotite schist with pegmatite streaks.
—1171+00 Pegmatite
—1170+50 Granite.
—1170+00 Biotite schist with pegmatite streaks
LEGEND
BRINFIELD TYPE SCHIST
BRINFIELD TYPE INJECTION SCHIST
PEGMATITE
Dip Degrees, Approx. Strike Bearing Degrees JOINTS
Tunnel S63°03'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION-STA 1170+00 TO 1180+00
20 10 0 20 40FT


118
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION - STA-1180+00 TO 1190+00
20 10 0 20 40FT
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
1190
1185
1180
1185+00
Bands of gray granite, pegmatite and diorite
Foliation dip 36°W
Pegmatite injection in branching veins. Hornblendic rock (diorite) occurs in bands together with foliated granite
Foliation dip 37°W
A massive diorite contacts the soft schist here. The contact rock occurs as a band about five feet thick, and is followed by gray granite. The diorite is the dominant rock for about one hundred feet, but a few small masses of schist also occur
Foliation dip 45°W
Small pegmatite lenses and knots in biotite schist Rock is soft and wet
Foliation dip 36°W
Flaky biotite type of schist Much banded injection
Foliation dip 42°W
Biotite schist Pegmatite bands.
Foliation dip 30°W
Banded injection.
Minor joints at right angles to foliation
MONSON GRANODIORITE
CONTACT
BRIMFIELD-WARE SCHIST
1190+00 Foliated gray granite with hornblende diorite bands
1189+50 Granitized biotite schist with pegmatite
1189+00 Massive hornblende diorite
1188+50 Pegmatite with biotite folia
1188+00 Garnetiferous biotite schist and pegmatite
1187+50 Granitized biotite schist and pegmatite
1187+00 Garnetiferous biotite schist and pegmatite
1186+50 Granitized biotite schist.
1186+00 Biotite schist with pegmatite streaks
1185+50 Garnetiferous granitized schist and pegmatite
1185+00 Coarse banded garnetiferous granite
Pegmatite and coarse granite bands
Foliation dip 35°W
Biotite injection schist
Foliation dip 40°W
Pegmatite lenses and feldspar knots.
Injection gneiss
Foliation dip 32°W
Foliation dip 57°W
Dense biotite schist. Foliation dip 30°W
Feldspar knots and lenses
Narrow pegmatite bands.
Coarse granite and pegmatite
Foliation dip 24°W
Banded injection
Strike N0°E Foliation Dip 30°W
1185+00 Coarse banded garnetiferous granite
1184+50 Granitized schist
1184+00 Biotite schist with pegmatite and garnet
1183+50 Granitized schist
1183+00 Biotite schist with pegmatite
1182+50 Biotite schist with pegmatite streaks
1182+00 Garnetiferous biotite schist with pegmatite lenses
1181+50 Biotite schist with feldspar crystals and pegmatite
1181+00 Garnetiferous biotite schist with pegmatite
1180+50 Biotite schist with feldspar crystals
1180+00 Biotite injection schist
LEGEND
BRIMFIELD TYPE SCHIST
BRIMFIELD TYPE INJECTION SCHIST
PEGMATITE
DIORITE
Tunnel S83°03'W
Dip Degrees, Approx.
Strike Bearing Degrees
JOINTS


GEOLOGIC SECTION NORTH WALL
—1260+00
Foliated granite
Coarse or pegmatitic granite
Foliation dip 30°W
Lenticular block of diorite
Blocks of diorite
Foliation dip 35°W
Gray foliated granite
Banded dark and light gray granite
Foliation dip 42°W
Foliation dip 36°W
Minor folding of foliation structure
Foliated gray granite and narrow diorite bands
Foliation dip 30°W
Ribbon gneiss of granite and diorite
Foliation dip 32°W
Banded granite and diorite
Pegmatite lens containing pink feldspar
Foliation dip 44°W
Diorite-granite bands in form of lenses and foliation of surrounding granite appear to bend around lens
Foliation dip 36°W
Ribbon gneiss of granite and diorite
Foliation dip 43°W
—1255+00
Diorite
NORTH
FLOOR PLAN
SOUTH
A feature of this section is the lack of jointing
N 78°E
LOCATION AND DESCRIPTION OF SPECIMEN
—1260+00 Granite gneiss or banded granite
—1259+50 Foliated granite
—1259+00 Foliated granite
—1258+50 Foliated granite
—1258+00 Diorite with pegmatitic bands
—1257+50 Gray granite and pegmatite
—1257+00 Banded diorite
—1256+50 Banded diorite and granite
—1256+00 Foliated granite
—1255+50 Hornblende diorite and granite
—1255+00 Foliated granite
N
—1255+00
Foliation dip 34°W
Foliated and banded granite
Hornblende diorite
Ribbon gneiss of diorite and granite
Diorite surrounded by coarse pegmatitic granite
Alternate bands of hornblende diorite and granite
Foliation dip 35°W
Coarse foliated gray granite
Foliation dip 41°W
Largely a coarse granite surrounding block-like masses of diorite
Foliation dip 37°W
Banded granite
Foliation dip 26°W
Largely diorite with granite bands and pegmatite
Irregular pegmatite bands and veins oriented nearly vertical
—1250+00
GEOLOGIC SECTION NORTH WALL
(Some diorite bands appear to be cut off by pegmatitic granite)
NORTH
FLOOR PLAN
SOUTH
A feature of this section is the lack of jointing
LOCATION AND DESCRIPTION OF SPECIMEN
—1255+00 Foliated granite
—1254+50 Foliated granite
—1254+00 Coarse banded diorite
—1253+50 Hornblende diorite
—1253+00 Foliated granite
—1252+50 Coarse granite
—1252+00 Foliated granite
—1251+50 Foliated granite
—1251+00 Foliated granite
—1250+50 Coarse hornblende diorite
—1250+00 Banded diorite and granite (ribbon gneiss)
Tunnel S 83°03'W
LEGEND
MONSON GRANODIORITE
DIORITE
PEGMATITE
Dip
Degrees
Approx
Strike
Bearing
Degrees
JOINTS
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA 1250+00 TO 1260+00
20 10 0 20 40 FT


126
GEOLOGIC SECTION NORTH WALL
1270+00
Foliation dip 38°W
Ramifying pegmatite veins
Gray foliated granite associated with hornblende diorite which occurs as bands of varying width and regularity
Ribbon gneiss
Foliation dip 45°W
Coarse granite, pegmatite and diorite
Foliation dip 55°W
Coarse granite or gneiss
Pegmatite lenses in gray granite
Foliation dip 55°W
Foliated diorite and narrow pegmatite bands
Banded gray granite
Narrow lenticular bands of diorite
Pegmatite occurs in small folds and crinkles
Foliation dip 54°W
Small scale folding of foliation
Ramifying pegmatite veins
Foliation dip 25°W
Banded diorite-ribbon gneiss
Strike N30°E
Foliation dip 45° (in section)
Foliated and gneissoid granite.
Coarse or pegmatitic granite or gneiss foliation is irregular
Pegmatite injection
Foliation dip 23°W
Pegmatite streaks and bands in diorite or dark granite
Coarse granite
Banded gneissoid granite contains pink feldspar
1265+00
Diorite
Pegmatite
NORTH
FLOOR PLAN
SOUTH
N76°E
60
N64°W
80
N56°E
70
LOCATION AND DESCRIPTION OF SPECIMEN
1270+00 Foliated granite
1269+50 Hornblende diorite
1269+00 Foliated granite
1268+50 Banded granitized schist and pegmatite
1268+00 Foliated granite
1267+75 Hornblende diorite
1267+50 Foliated granite
1267+00 Banded hornblende granite
1266+50 Hornblende granite
1266+00 Foliated granite
1265+50 Dark coarse granite
1265+00 Coarse foliated granite with pink feldspar
N
1265+00
Pegmatite merges into pink coarse granite
Banded gneiss
Foliation dip 33°W
Coarse injection gneiss or schist
Black biotite and hornblende granite or diorite Narrow bands of light granite and pegmatite are folded and squeezed
Banded diorite or ribbon gneiss
Small masses of diorite surrounded by granite
Foliation dip 34°W
Banded granite and diorite
Foliation dip 80°W
Granite contains pegmatite
Coarse or pegmatitic granite.
Foliation dip 35°W
Foliation dip 55°W
Banded granite and diorite
Foliation dip 36°W
Foliated granite, narrow pegmatite bands
1260+00
Contact zone is soft, containg clay gouge
Diorite
NORTH
FLOOR PLAN
SOUTH
N11°E
70
80
N56°E
N56°E
LOCATION AND DESCRIPTION OF SPECIMEN
1265+00 Coarse foliated granite with pink feldspar
1264+50 Banded hornblende diorite and pegmatite
1264+00 Coarse foliated granite with pink pegmatite
1263+50 Hornblende diorite
1263+00 Banded granite and diorite
1262+50 Coarse foliated granite
1262+00 Foliated hornblende granite
1261+50 Diorite and pegmatite
1261+00 Foliated granite.
1260+50 Foliated granite and diorite.
1260+00 Granite gneiss or banded granite.
LEGEND
MONSON GRANODIORITE
DIORITE
PEGMATITE
Dip
Degrees
Approx.
Strike
Bearing
Degrees
JOINTS
Tunnel 383° 05' W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1260+00 TO 1270+00
20 10 0 20 40FT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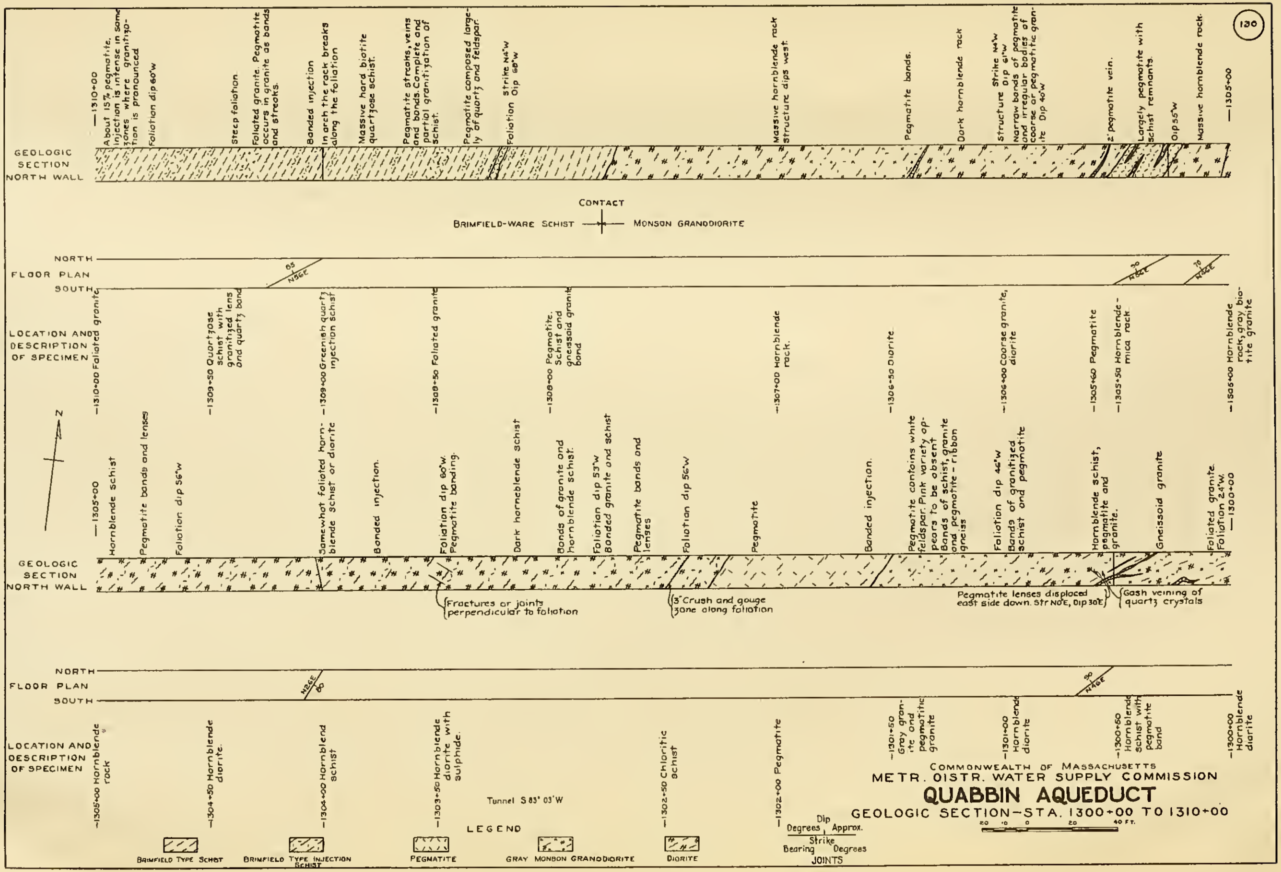
GEOLOGIC SECTION NORTH WALL
1280+00
Bands of hornblende diorite with the granite Also bands of pegmatite.
Foliation dip 55°W
Streaks and small blotches of pink pegmatite in diorite.
Gray granite and diorite occur in bands. Foliation dip 23°W Granite contains pegmatite bands
Foliation dip 61°W
Gray granite, pegmatite in lenses and bands
Foliation dip 43°W Hornblende diorite borders pegmatite
Foliation dip 30°W
Dark hornblendic granite
Foliation dip 20°W
Irregular masses of pegmatite in granite
Foliation dip 42°W
Light and dark gneissoid granite
Numerous pegmatite bands and streaks.
Foliation dip 33°W
Thin irregular pegmatite veins cut foliation.
Foliation dip 41°W
1275+00
NORTH
FLOOR PLAN
SOUTH
Jointing is not prominent
LOCATION AND DESCRIPTION OF SPECIMEN
1280+00 Gray foliated granite
1279+50 Banded gneiss of coarse hornblende diorite and pegmatite
1279+00 Gray foliated granite and pegmatite
1278+80 Hornblende diorite and pegmatite
1278+50 Coarse hornblende diorite
1278+00 Coarse hornblende granite
1277+50 Coarse hornblende granite
1277+00 Hornblende diorite and coarse granite
1276+50 Hornblende diorite and coarse granite
1276+00 Gray foliated granite
1275+50 Gray granite
1275+00 Hornblende granite
N
1275+00
Coarse granite.
Ribbon gneiss of diorite and pegmatite. Also bands of hornblende granite.
Gray granite
Coarse pegmatitic granite.
Narrow band of diorite.
Fine and coarse granite Foliation dip 42°W
Pegmatite lenses in granite Foliation 50°W Irregular foliation.
Gray granite
Banded light and dark granite Foliation dip 33°W
Coarse hornblende granite and gneiss.
Hornblende granite or gneiss.
Foliation strike N11°E. Dip 66°W.
Banded gray granite
Foliation dip 40°W
Bands of hornblende diorite and pegmatite.
Banded gneissoid and pegmatitic granite Hornblende granite and diorite.
Irregular pegmatite veins.
1270+00
GEOLOGIC SECTION NORTH WALL
Patches of gray granite surrounded by dark hornblende granite. Foliation is somewhat irregular or crinkled
NORTH
FLOOR PLAN
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
1275+00 Gray granite Hornblende diorite and coarse hornblende granite gneiss
1274+50 Pegmatitic granite.
1274+00 Pegmatitic granite
1273+50 Foliated granite
1273+00 Foliated granite
1272+50 Foliated granite.
1272+00 Coarse hornblende diorite.
1271+50 Hornblende diorite
1271+00 Hornblende diorite
1270+50 Hornblende diorite
1270+00 Foliated granite
LEGEND
MONSON GRANODIORITE
DIORITE
PEGMATITE
Dip Degrees Approx. Strike Bearing Degrees JOINTS
Tunnel S83°03'W
COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1270+00 TO 1280+00
20 10 0 20 40 FT

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1280+00 TO 1290+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
Shotcrete Contact
Faced with quartz
Tunnel S85°05'W
LEGEND
MONZON
GRANODIORITE
DIORITE
PEGMATITE
Top
Degrees
Approx.
Strike
Degrees
Boring
JOINTS

COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1290+00 TO 1300+00
LEGEND
MONSON GRANODIORITE
DIORITE
PEGMATITE
Dip Degrees Approx.
Strike Degrees
Bearing
JOINTS
Tunnel S85°03'W
PERMANENT TIMBERING
GEOLOGIC SECTION
NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
Massive hornblende rock
Folation strike N6°E dip 35°W
Lens-like pegmatite bodies also elongate bands pegmatite contains pink feldspar
Schist stringers.
Folated granite contents orgranite and schist generally parallel to major structure
Folation dip62°W
Banded injection
Massive hornblende schist or diorite. Streaks and bands of white pegmatite
Pink feldspar crystals in gneissoid granite.
Banded injection. Folation dip 35°W
Coarse folated granite. Pink feldspar a feature
Gneissoid granite with pink feldspar crystals. Strike N6°E. Folation dip 35°W
Coarse granite contains fractured and porfirhy altered
Pegmatite contains pockets and seams of clayey substance. Rock is very soft
Pink feldspar a feature.
Pegmatitic granite.
Hornblende diorite
Folation dip 82°W
—1300+00
—1295+00
Pegmatite bands
Banded injection with pink feldspar a feature
Discontinuous minor joints filled with quartz. Joint surfaces blocky ground. Black faces coated with carbonate
—1300+00 Hornblende diorite
—1298+50 Folated biotite granite.
—1297+50 Folated biotite granite
—1295+50 Pink gneissoid granite
—1294+50 Gneissoid granite
—1293+00 Granite gneiss
—1292+00 Diorite.
—1291+50 Pegmatitic granite
—1290+50 Pegmatitic gneissoid granite
—1290+00 Diorite gneiss
—1295+00 Diorite. Corbonate material and gneissoid granite wall rock.
—1293+50 Coarse granite gneiss.
—1292+00 Diorite.
—1291+50 Pegmatitic granite
—1291+00 Pegmatitic gneissoid granite
—1290+50 Coarse granite gneiss.
—1290+00 Folation dip 45°W.
Zone of intense soak-ing. Pegmatite follows small folds and crumples
—1289+00
Point folated granite with hornblende diorite
—1286+50 Gneissoid granite Pink granite
Massive hornblende diorite.
Folation dip 60°W
Hornblende schist and pegmatite bands
Coarse granite gneiss.
—1286+00 Pink gneissoid granite.
Coarse gneiss
—1287+00 Pink gneissoid granite
Folation dip 84°W
Bands of pegmatite, granite and hornblende schist
Coarse folated granite or gneiss
Pegmatite lens in diorite.
Pegmatitic granite.
—1288+50 Pink porphyritic granite gneiss.
Schist inclusion.
—1289+50 Pink pegmatitic granite.
—1290+50 Hornblende diorite
—1290+00 Hornblende diorite.
Coarse gneissoid granite
—1295+00
—1300+00 Hornblende diorite
N



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COMMONWEALTH OF MASSACHUSETTS
METR. DISTR. WATER SUPPLY COMMISSION
QUABBIN AQUEDUCT
GEOLOGIC SECTION—STA. 1300+00 TO 1310+00
GEOLOGIC SECTION NORTH WALL
FLOOR PLAN
NORTH
SOUTH
LOCATION AND DESCRIPTION OF SPECIMEN
CONTACT
BRIMFIELD-WARE SCHIST
MONSON GRANODIORITE
1310+00
About 15% pegmatite. Injection is intense in some zones where granitization is pronounced
Foliation dip 60°W
Steep foliation
Foliated granite. Pegmatite occurs in granite as bands and streaks.
Banded injection
In arch the rock breaks along the foliation
Massive hard biotite quartzose schist.
Pegmatite streaks, veins and bands. Complete and partial granitization of schist.
Pegmatite composed largely of quartz and feldspar
Foliation Strike N4°W Dip 68°W
Massive hornblende rock Structure dips west.
Pegmatite bands.
Dark hornblende rock
Structure Strike N4°W Dip 61°W
Narrow bands of pegmatite and irregular bodies of coarse or pegmatitic granite Dip 40°W
2' pegmatite vein.
Largely pegmatite with schist remnants.
Dip 55°W
Massive hornblende rock.
1305+00
1310+00 Foliated granite
1309+50 Quartzose schist with granitized lens and quartz band
1309+00 Greenish quartz injection schist
1308+50 Foliated granite
1308+00 Pegmatite. Schist and gneissoid granite band
1307+00 Hornblende rock.
1306+50 Diorite
1306+00 Coarse granite, diorite
1305+60 Pegmatite
1305+50 Hornblende-mica rock.
1305+00 Hornblende rock, gray biotite granite
1305+00
Hornblende schist
Pegmatite bands and lenses
Foliation dip 56°W
Somewhat foliated hornblende schist or diorite
Banded injection.
Foliation dip 60°W. Pegmatite banding.
Dark hornblende schist
Bands of granite and hornblende schist.
Foliation dip 53°W Banded granite and schist
Pegmatite bands and lenses
Foliation dip 56°W
Pegmatite
Banded injection.
Pegmatite contains white feldspar. Pink variety appears to be absent. Bands of schist, granite and pegmatite - ribbon gneiss
Foliation dip 46°W Bands of granitized schist and pegmatite
Hornblende schist, pegmatite and granite.
Gneissoid granite
Foliated granite. Foliation 24°W.
1300+00
Fractures or joints perpendicular to foliation
3' Crush and gouge zone along foliation
Pegmatite lenses displaced east side down. Str N0°E, Dip 30°E
Gash veining of quartz crystals
1305+00 Hornblende rock
1304+50 Hornblende diorite.
1304+00 Hornblend schist
1303+50 Hornblende diorite with sulphide.
1302+50 Chloritic schist
1302+00 Pegmatite
1301+50 Gray granite and pegmatitic granite
1301+00 Hornblende diorite
1300+50 Hornblende schist with pegmatite band
1300+00 Hornblende diorite
Tunnel S 83° 03' W
LEGEND
BRIMFIELD TYPE SCHIST
BRIMFIELD TYPE INJECTION SCHIST
PEGMATITE
GRAY MONSON GRANODIORITE
DIORITE
Dip Degrees Approx.
Strike
Bearing Degrees
JOINTS
20 10 0 20 40 FT.

5118 113

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BOOKBINDING CO., INC.

MAY — 1991

100 CAMBRIDGE STREET
CHARLESTOWN, MASS